A CRITICAL APPRAISAL OF THE USE OF DISPLACEMENT VENTILATION IN COMMERCIAL BUILDINGS

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ABSTRACT

The work in this thesis examines recent research and current design practice relating to the use of displacement ventilation in commercial buildings to assess the degree of success that has been achieved. The findings show that there is uncertainty in several areas of performance. The major area of concern is the inability of this method of ventilation to maintain thermal comfort in typical commercial office conditions due to restrictions on supply airflow rates. Attempts to overcome this problem with supplementary cooling devices have presented a risk of negating the air quality benefits and the nature of these risks are exposed using smoke visualisation techniques. It is concluded that it is inaccurate to describe the use of displacement ventilation system as such, when used in combination with any form of chilled ceiling device.

A feasibility study is completed to examine the performance of an alternative form of air supply diffuser, namely a textile diffuser. This indicates that it may be possible to provide a displacement ventilation system that will maintain thermal comfort and good air quality in typical commercial office conditions without the need for supplementary cooling devices. Further experimental work results in data confirming the performance characteristics of the textile diffuser used for displacement ventilation supply.

It is established that it is technically feasible to provide a displacement ventilation system with a volume flow rate sufficiently high to provide 50 W/m^2 of cooling capacity. Additionally, at this flow rate, the displacement flow regime is established to the full height of the occupied zone, to ensure the desired air quality in the space. It is concluded that the low draught risk associated with textile diffusers make them the preferred option for any low level supply system.

CERTIFICATE OF RESEARCH

This is to certify that, except where specific assistance is attributed and reference is made, the work described in this thesis is that of the candidate. Neither this thesis nor any part of it, has been presented, or is currently submitted, in candidature for any degree at any other University.

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ACKNOWLEDGEMENT OF ASSISTANCE GIVEN TO THE AUTHOR

Dr Farshad Alamdari, the Section Leader of the Microclimate Centre at the Building Services Research and Information Association, Bracknell, UK provided the test data for comparison with the results of the experimental work carried out by the author in the feasibility study. These are shown in Figures 5.7 – 5.10, (the pale blue profiles).

The author obtained all other data, other than those attributed in the text.

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PROFESSIONAL ACKNOWLEDGEMENTS

The initial trigger for this research project was a technical presentation on the benefits of displacement ventilation given by a Mr Terry Wyatt at a technical meeting of the South Wales Region of the Chartered Institution of Building Services Engineers, (CIBSE). Mr Wyatt, a recipient of the CIBSE Silver Medal for his work on displacement ventilation, is Research and Development Partner with Consulting Engineers Hoare Lea and Partners.

The presentation explained the air quality and low energy consumption benefits associated with the use of displacement ventilation when compared with the more conventional dilution method of ventilation, and therefore introduced a topic that spanned the areas of primary interest of the author.

A decision was subsequently made that displacement ventilation provided a suitable area for research. In order to satisfy the 'collaborating with industry' requirement, Mr Wyatt was approached to discuss the scope for collaboration with his firm, Hoare Lea and Partners. Mr Wyatt was very supportive and offered to assist with advice and information in any way that he could but suggested that collaboration with a Contractor might be more beneficial in the long term. He believed that they would be more likely to be able to offer financial support, should it become necessary.

Mr Wyatt knew that Mr John Bailey, a Director of Matthew Hall Ltd, a Mechanical and Electrical Engineering Contracting Company, (a member of the AMEC Group), was particularly interested in developments in displacement ventilation and organised a meeting of introduction. As a result of this meeting Matthew Hall agreed to collaborate

on a research project, initially offering introductions to building operators using displacement ventilation and manufacturers of displacement ventilation equipment.

Most significantly, Matthew Hall Ltd was sponsoring a displacement ventilation related research project at The Building Services Research and Information Association, (BSRIA), Microclimate Centre. This led to an invitation by Dr Farshad Alamdari, the project leader, to visit BSRIA to discuss the work associated with the project. The project was to study the combined performance of chilled ceilings and displacement ventilation in the office environment. The outcome of this visit was an invitation to join the research team for a period of four months. It was the view of Dr Alamdari that the project would benefit from an external collaborator with industry experience, and in return use of the test facility was offered for any complementary experimental work that was identified.

The University of Glamorgan agreed to the release of the author for this exercise from October 1994 to January 1995, utilising a successful University Funding of Research (UNIR) bid to cover travelling and replacement teaching costs. With this agreement in place, BSRIA effectively replaced Matthew Hall Ltd as the collaborating organisation.

PERSONAL ACKNOWLEDGEMENTS

My sincere thanks go to Dr Max Graham for his encouragement and support, and also to Professor Stan Wild for his guidance in the production of this submission.

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Finally, I must thank Maureen, Philip, Penelope and Emily for the sacrifices that they have made (again) to allow me the time to pursue this project to completion.

GLOSSARY OF TERMS/ABBREVIATIONS

ASHRAE	American Society of Heating Refrigeration and Air-conditioning Engineers
BSRIA	Building Services Research and Information Association
CFD	Computational fluid dynamics
CIBSE	Chartered Institution of Building Services Engineers
CO_2	Carbon Dioxide
Coanda Effect	Specifically – the tendency for an air jet to attach itself to a solid convex body as a result of the pressure variation that perpendicular to the curved streamlines. Colloquially used to describe wall jet attachment.
Δt	Temperature difference
DETR	Department of Environment Transport and the Regions
Dilution Ventilation	(Also mixing ventilation) Momentum induced air flow
Displacement Ventilation	Buoyancy induced air flow
EC	European Commission
K	Degrees Kelvin
Mixing Ventilation	(Also dilution ventilation) Momentum induced air flow
PMV	Predicted Mean Vote
PPD	Predicted percentage of dissatisfied

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Chapter 1

Introduction

1.0 INTRODUCTION

1.1 Introduction

It is now established (Neilson PV 1993, Alamdari F et al 1994) that 'Displacement Ventilation' offers the dual advantage over 'Dilution Ventilation' of providing better air quality with lower energy consumption.

This thesis identifies the potential benefits of using displacement ventilation in commercial buildings in the UK. It establishes the current state of research into the use of displacement ventilation, and investigates the limitations experienced in its application to office workplace ventilation.

The potential benefits and current research are identified from work reported in the literature. The limitations currently experienced are also identified from the literature, and are supported by structured interviews with eminent practitioners. In order to verify the limitations identified from the literature and from interviews, experimental work was conducted at the Building Services Research and Information Association (BSRIA) Test Facility in Crowthorne. The same test facility has been used to validate the identified solutions for reducing these limitations. Some of the results from the experimental work have been presented to researchers and practitioners at conferences and further conference or journal publications are planned.

1.1.1 Principles of ventilation

Ventilation can be defined as the supply to and removal of air from a space, to improve or maintain the indoor air quality, (EC Report No. 11 1992). Although variously described, ventilation systems can be classified primarily as dilution ventilation, (usually referred to as mixing), or displacement ventilation.

Dilution ventilation is traditionally the preferred method in the UK. (BSRIA COP 17/99). This method achieves the required indoor air quality by continuously diluting the indoor pollutants by mixing the room air with cleaner incoming "fresh" air, whilst removing the diluted mixture at the same rate. With this method the occupants are never breathing the "fresh" air as it has always been mixed with polluted air before entering the occupied zone.

Displacement ventilation has increasingly been used in the UK, despite the fact that until recently there has been no authoritative guidance on its use in commercial buildings (BSRIA COP 17/99). This method achieves the required indoor air quality by gently introducing the cleaner incoming "fresh" air near the floor and at a temperature slightly lower than the design room air temperature. The cool air flows slowly over the floor and as the air is warmed by contact with warm surfaces it rises and displaces the contaminated air above. Convection currents from any heat sources in the room assist the general upward movement of air until it is exhausted at high level. As occupants are one such heat source, the convective plume created by their own body heat is drawing clean unmixed air through their breathing zone.

Floor mounted swirl diffusers that are designed to deliberately mix supply air with room air to avoid cold draughts at the feet are sometimes described as providing displacement ventilation because the air is supplied at low level. This is not consistent with the definition of displacement ventilation given in the paragraph above, and for the purposes of this thesis, displacement ventilation will be taken to mean buoyancy driven ventilation where the design intent is to avoid mixing of supply and room air. Most natural ventilation designs work on the displacement ventilation principle. The principles of displacement ventilation and dilution or mixing ventilation are illustrated in Figure. 1.1 below.

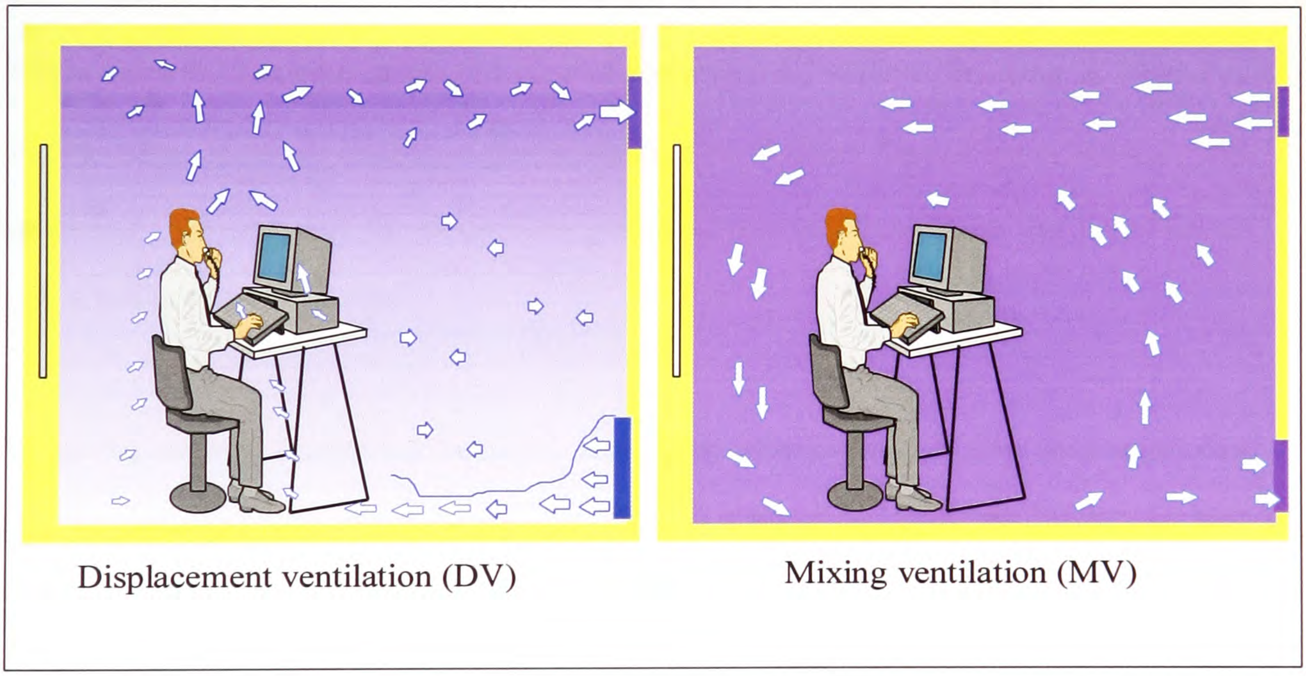


Figure 1.1. The Principles of Displacement Ventilation and Mixing Ventilation

1.1.2 Ventilation effectiveness

In order to recognise the relative merits of displacement ventilation over dilution ventilation, the ventilation effectiveness must be considered.

(EC Report No. 11 1992) defines ventilation effectiveness (ε_v) as the relationship between the pollution concentration in the exhaust air (C_e) and the pollution concentration in the breathing zone (C_i).

$$\varepsilon_V = \frac{C_e}{C_i}$$

The ventilation effectiveness depends on the air distribution and the location of the pollution sources in the space. Where the main source of pollution is occupants, i.e. in non-industrial buildings, pollution sources are usually evenly distributed in the space. Where there is complete mixing of air and pollutants C_e will be the same as C_i and ε_v will be unity. If the air quality in the breathing zone is better than in the exhaust, ε_v will be greater than one, and the desired air quality in the breathing zone can be achieved with a lower ventilation rate.

As can be seen in Figure 1.2 below, a ventilation effectiveness higher than unity can only be achieved with displacement ventilation. This is the basis for the claims that displacement ventilation will provide better air quality with lower energy use. It is likely that the values for ventilation effectiveness for displacement ventilation are in fact higher than those indicated in Figure 1.2. The concentration C_i is used assuming that the concentration in the occupied zone is uniform and therefore is the same as the concentration in the breathing zone. The concept of a personalised air supply by convective plume identified in Figure 1.1 above suggests that for displacement ventilation the concentration in the breathing zone will be lower than in the general mass of air in the occupied zone. The problem of how to properly assess the ventilation effectiveness is identified in the literature review. Figure 1.2 also illustrates that displacement ventilation is only effective when the supply air temperature is lower than the room air temperature.

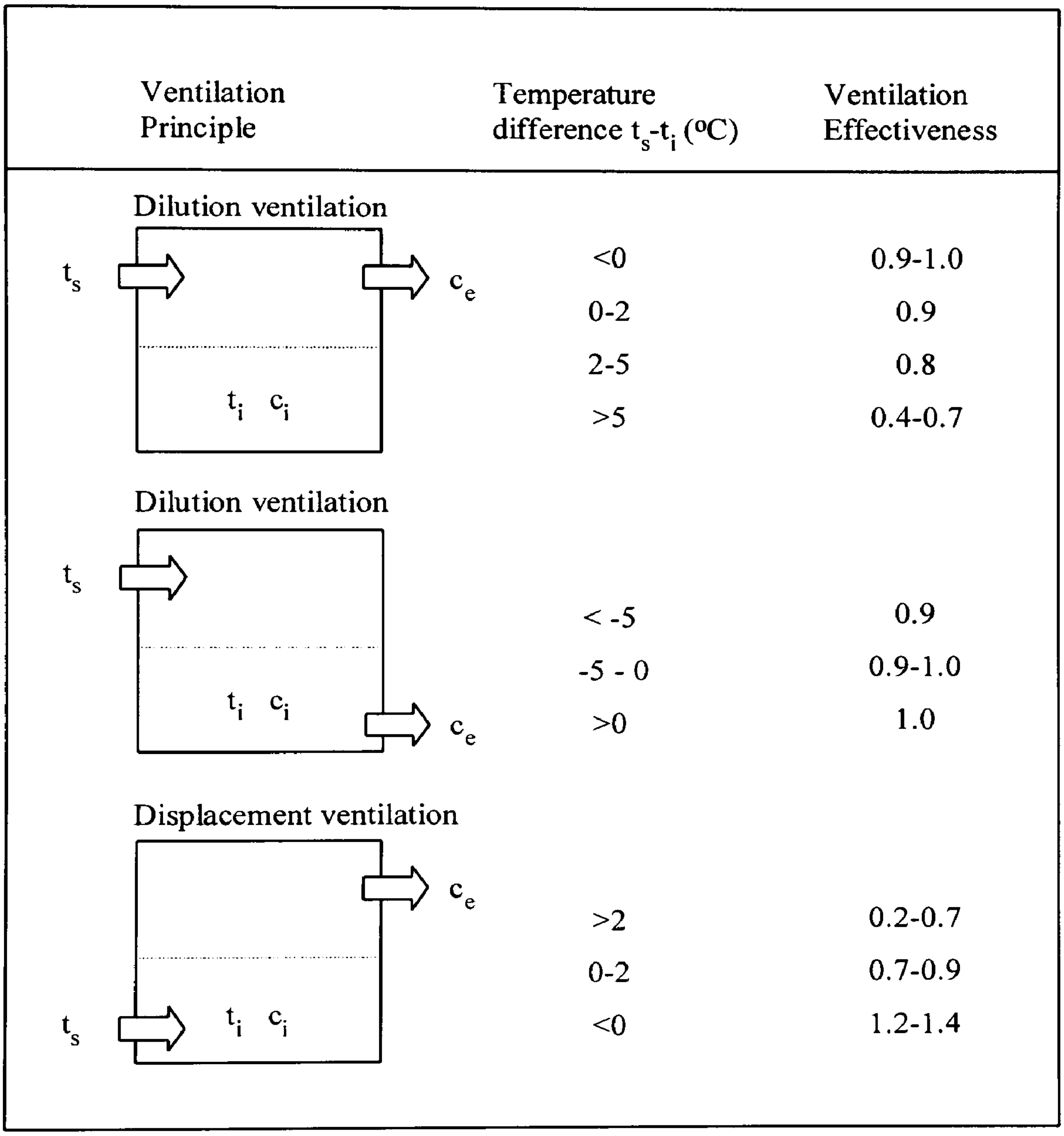


Figure 1.2 Ventilation effectiveness in the breathing zone for different methods of ventilation. (Source: EC Report No. 11 1992).

If the air quality in the breathing zone is poorer than the exhaust air, ε_v will be less than one and higher ventilation rates will be required to satisfy a particular air quality requirement.

To estimate ventilation effectiveness, it is useful to divide the space into two zones. One is the air supply zone and the other is the remainder of the space. With dilution ventilation the supply zone is usually above the occupied zone, to avoid draught risk. The best conditions are achieved when the mixing is so efficient that the two zones are indistinguishable. As can be seen in Figure 1.2, if the air supply and extract are both at high level, (often dictated by architectural or structural constraints), and the temperature difference (t_S-t_i) between the supply air and the room air is greater than 5K, then the air is reluctant to enter the occupied zone. In this situation, considerable short-circuiting occurs which results in very low values of ventilation effectiveness.

With displacement ventilation there is a supply zone that is also the occupied zone, and an exhaust zone above. The best conditions are achieved when there is minimal mixing between exhaust and supply zone.

The ventilation effectiveness can be calculated by numerical simulation or by experimental measurement. If data is not available, the information in Figure 1.2 provides reasonable guidance for dilution ventilation and, (subject to reservations over measuring the concentrations of pollutants in the breathing zone identified above), for displacement ventilation.

1.2 Dilution and Displacement Ventilation Theory

1.2.1 Dilution Ventilation (Momentum induced air flow)

The flow of air caused by a momentum source is called a jet. The study of the behaviour of jets is a well-established research area within the field of ventilation engineering. Contemporary guidance in this field, (ASHRAE 1998, BSRIA TN 3/90, CIBSE 1986), is largely based on the original work by Straub (1956)

1.2.1.1 Room Air Diffusion Principles

Ventilation air is normally supplied through air outlets at higher velocities than would be acceptable within the occupied zone. This supply air may be above, below or equal to the room air temperature. Effective room air diffusion therefore relies on:

- Entrainment of room air by the primary airstream before it enters the occupied zone to reduce air movement and temperature differences to an acceptable level.
- Overcoming the effects of natural convection and radiation within the room.

1.2.1.2 Velocity decay

As soon as air leaves a supply device the boundary of the jet begins to spread due to the process of turbulent diffusion or mixing with the surroundings. The influence of this diffusion process is to entrain room air and reduce the speed of the airstream as it crosses the space. At a certain distance from the supply device the diffusion process will reach the centre line of the jet, and the centre line velocity will decay. The diffusion will continue until the jet can no longer be distinguished from the bulk of the room air. A typical velocity decay situation is shown in Figure 1.3. The decay occurs in 4 stages (Nevins 1976). In the first stage that extends for approximately four supply device diameters or widths, the velocity at the centre line remains constant. The second stage that extends eight to ten diameters is the transitional zone. The main zone that dominates the characteristic jet profile extends for 10 to 100 diameters depending on the initial velocity and the device shape. In this zone the type of supply device chosen dictates the relationship between the centre-line velocity of the jet and the distance from the source. The final zone of the jet is where the velocity quickly decays to a low value and the jet becomes indistinguishable from its surroundings.

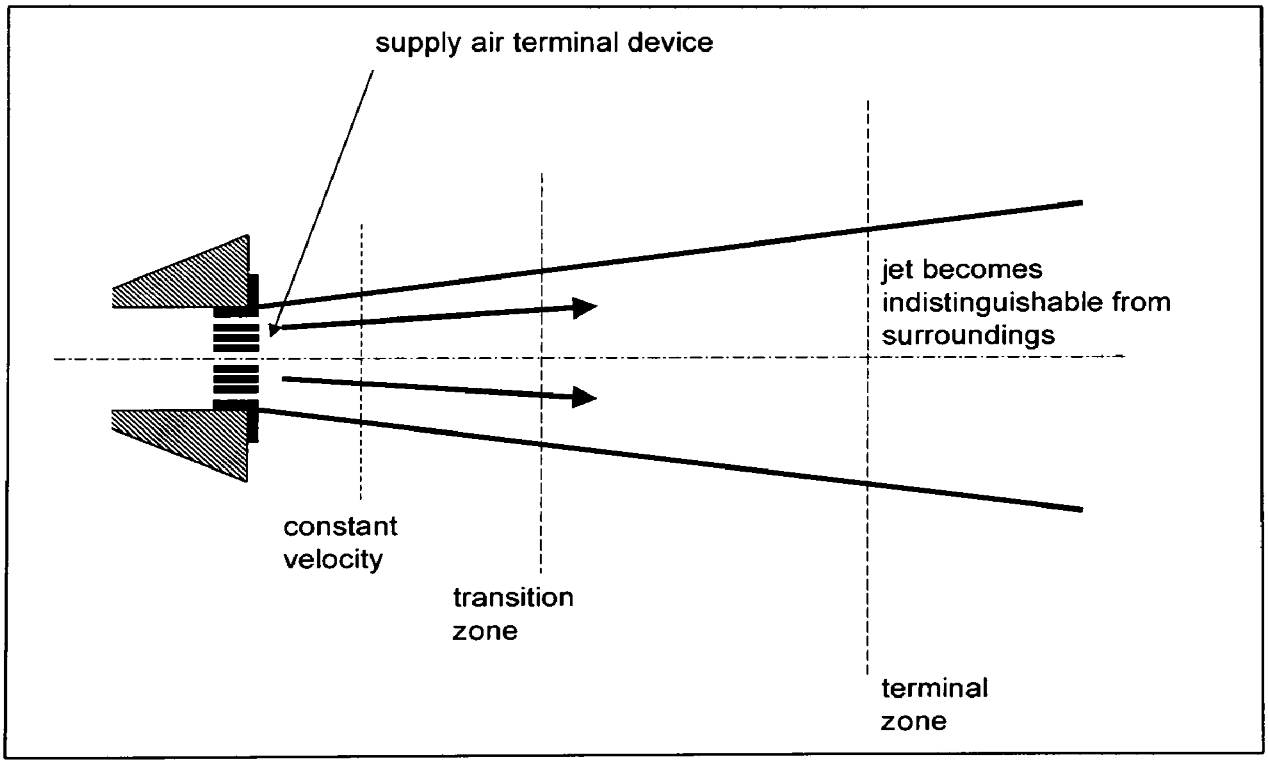


Figure 1.3 Velocity Decay of a Free Jet

The basic aerodynamic performance of an incoming jet is usually described in terms of the throw, spread and drop of the jet. These are parameters that in relation to a particular terminal velocity define a contour of constant velocity of the jet. The throw is the longitudinal distance from the supply outlet of the jet to the extremity of this envelope. For throw, the defining velocity contour is usually 0.5 m/s (ISO 3258 1976). The horizontal spread is the maximum dimension of the jet envelope measured in the horizontal plane. The defining velocity contour is also usually 0.5 m/s (ISO 3258). The drop is the vertical distance from the centre line of the jet outlet to the underside of the envelope. The defining contour is usually 0.25 m/s (ISO 3258). Manufacturers will often give additional values for lower velocities, which are of more value to the designer. Figures 1.4 and 1.5 illustrate these parameters.

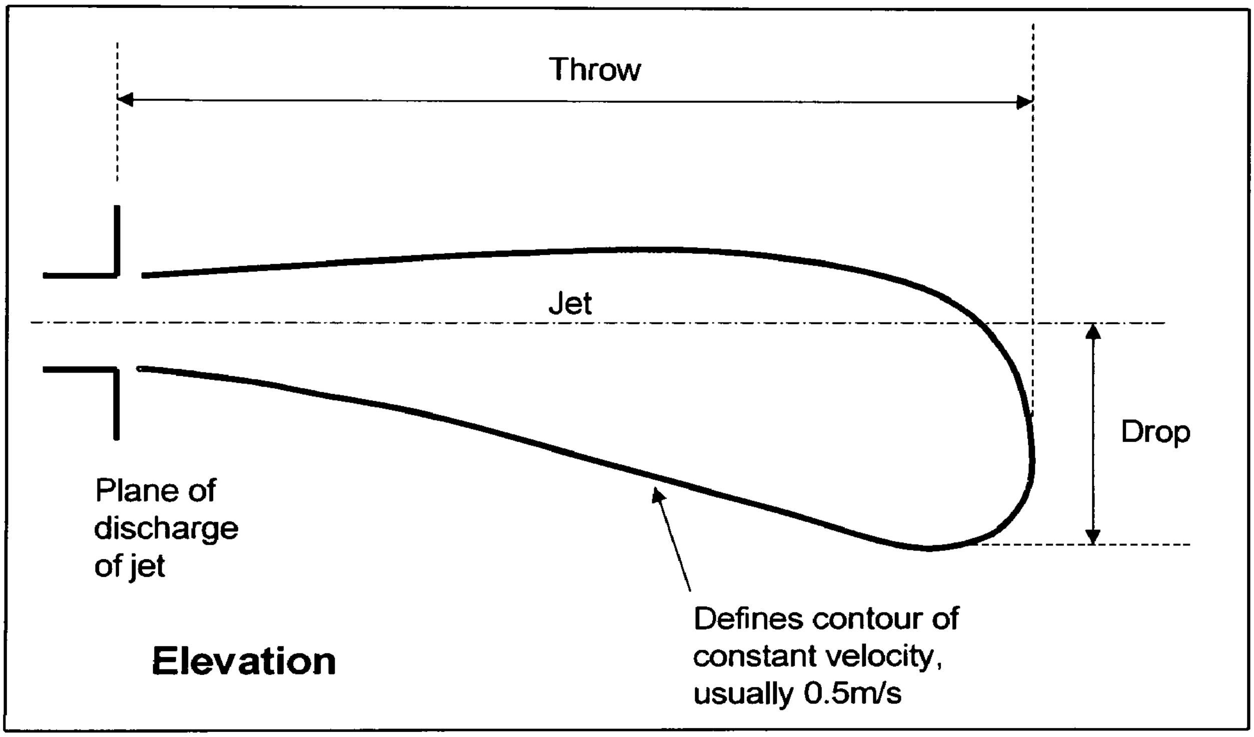


Figure 1.4 Throw and drop of an air supply jet

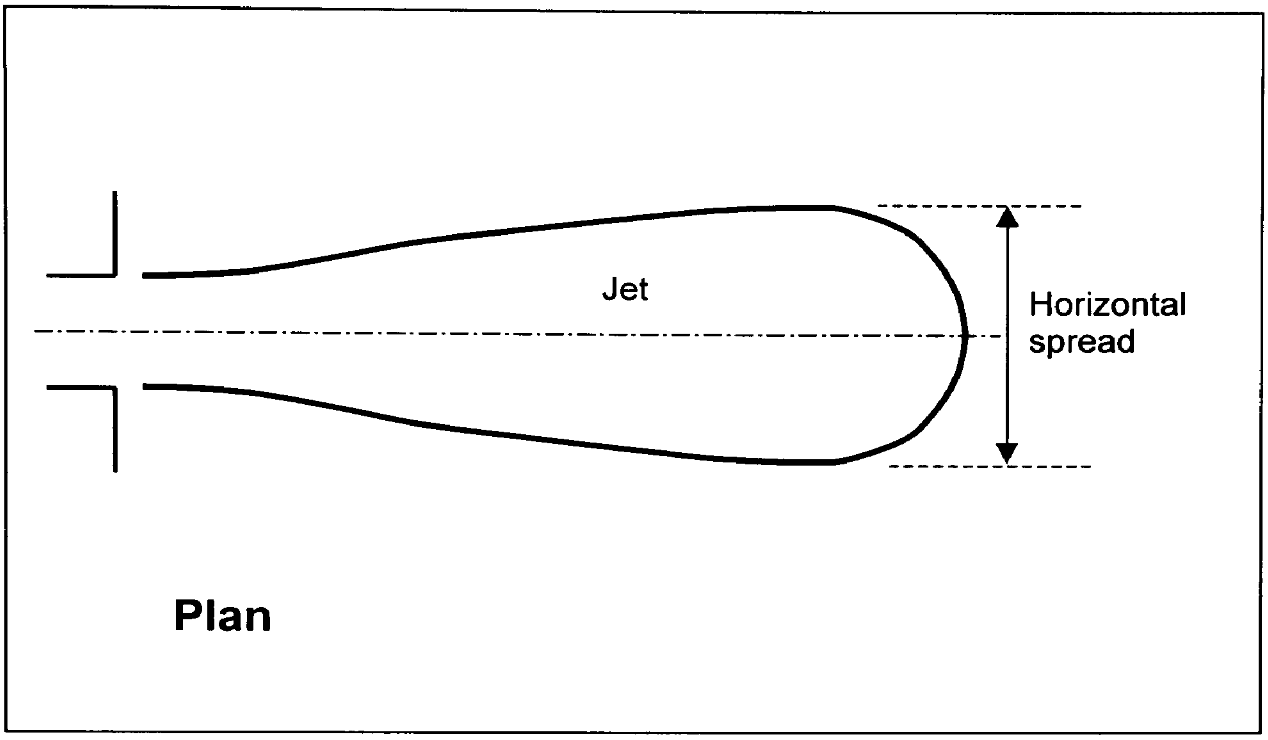


Figure 1.5 Spread of an air supply jet

Further detail on the theory and design of supply devices and room air diffusion can be obtained from Etheridge and Sandberg (1996).

1.2.2 Displacement Ventilation (Buoyancy induced air flow)

The general principles of low level supply air diffusers used for displacement ventilation systems are described in various texts, but are summarised by Skistad (1994) as described below.

When air is discharged at low velocity, its temperature determines how the air behaves. If the supply air temperature is the same as the room air temperature, the air will flow horizontally into the space as shown in Figure 1.6

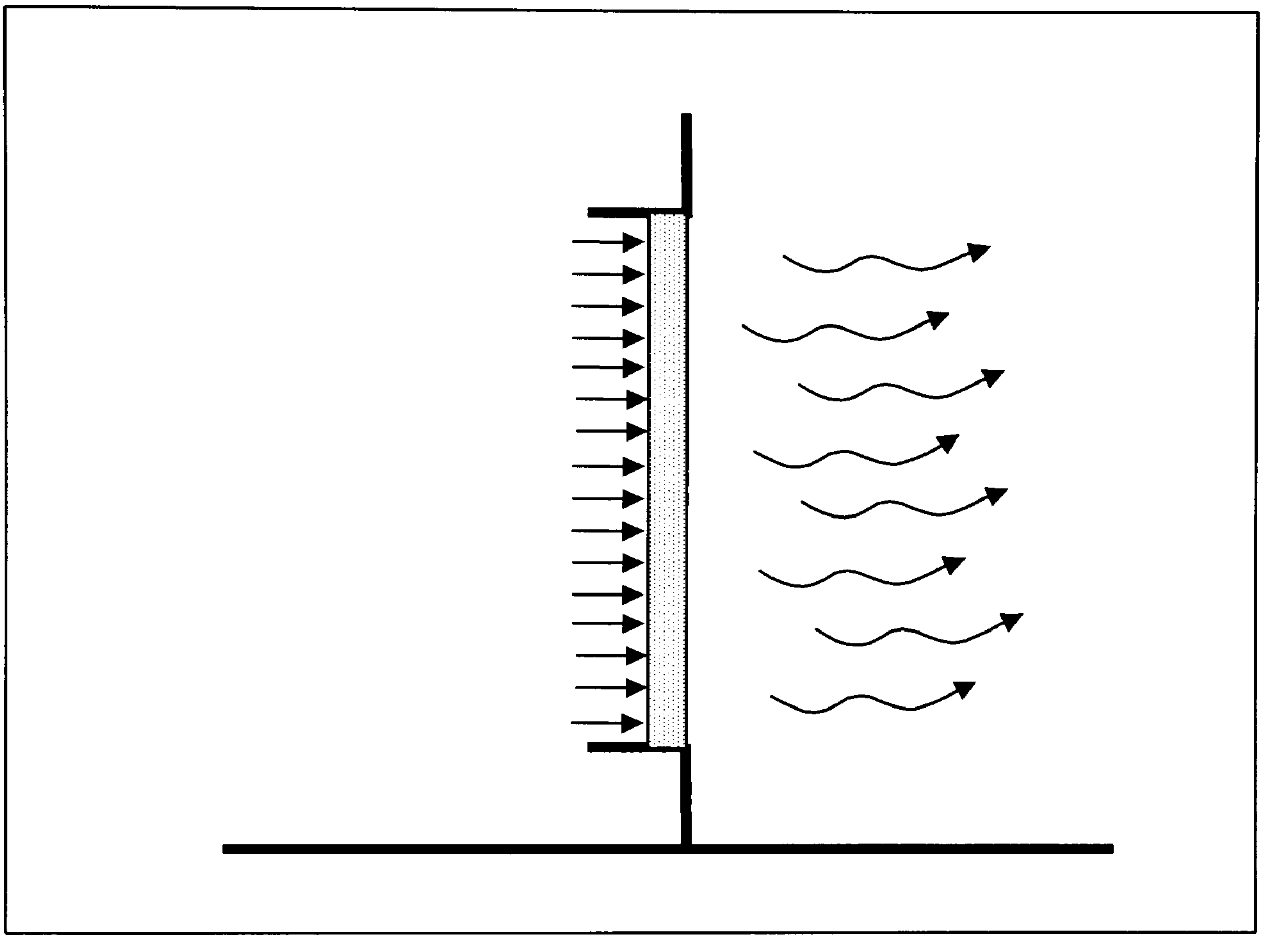


Figure 1.6 Isothermal air supply from a filter mat

If the supply air is warmer than the room air, it will rise towards the ceiling, as shown in Figure 1.7. This means that the ventilation air cannot be used to provide part of the heating load for the room. For displacement ventilation to develop, the supply air must be at least 0.5 ^{o}C cooler than the room air (at the point of introduction). When this is done, the supply air current will behave like a waterfall cascading from the supply unit as shown in Figure 1.8. In front of the supply unit, close to the floor, there will be a zone where the air velocities are much higher than the exit velocity, and where the temperature is lower than the room air temperature. A major concern in the design of displacement ventilation is to avoid draught along the floor.

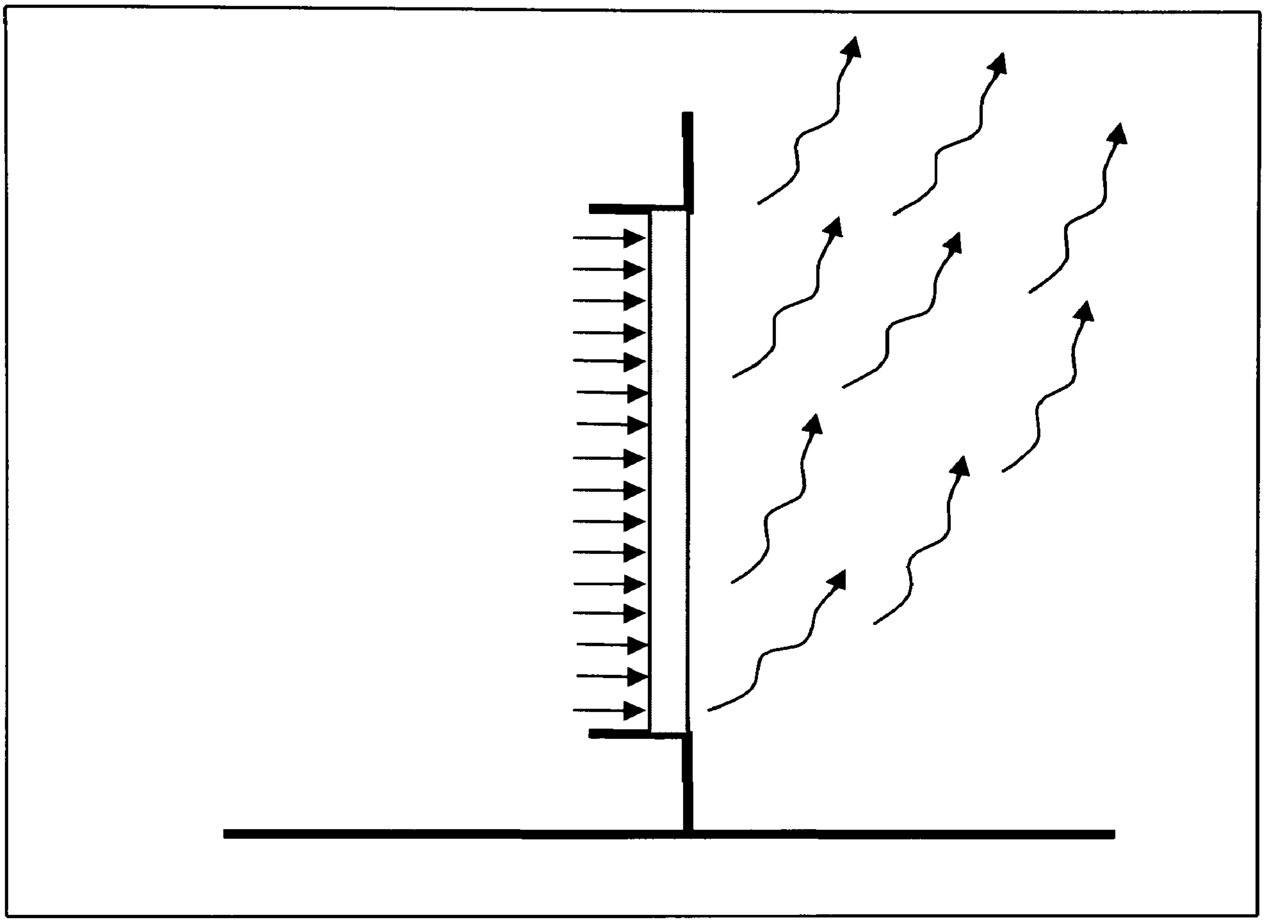


Figure 1.7 Warm air supply from a filter mat

The exit velocity from the diffuser, or face velocity is defined as the supply air volume divided by the gross frontal area of the supply unit, i.e.

$$u = \frac{V}{A}$$

where u = face velocity (m/s)

V = Volume flow rate (m^3/s)

A = free area of the supply unit (m^2)

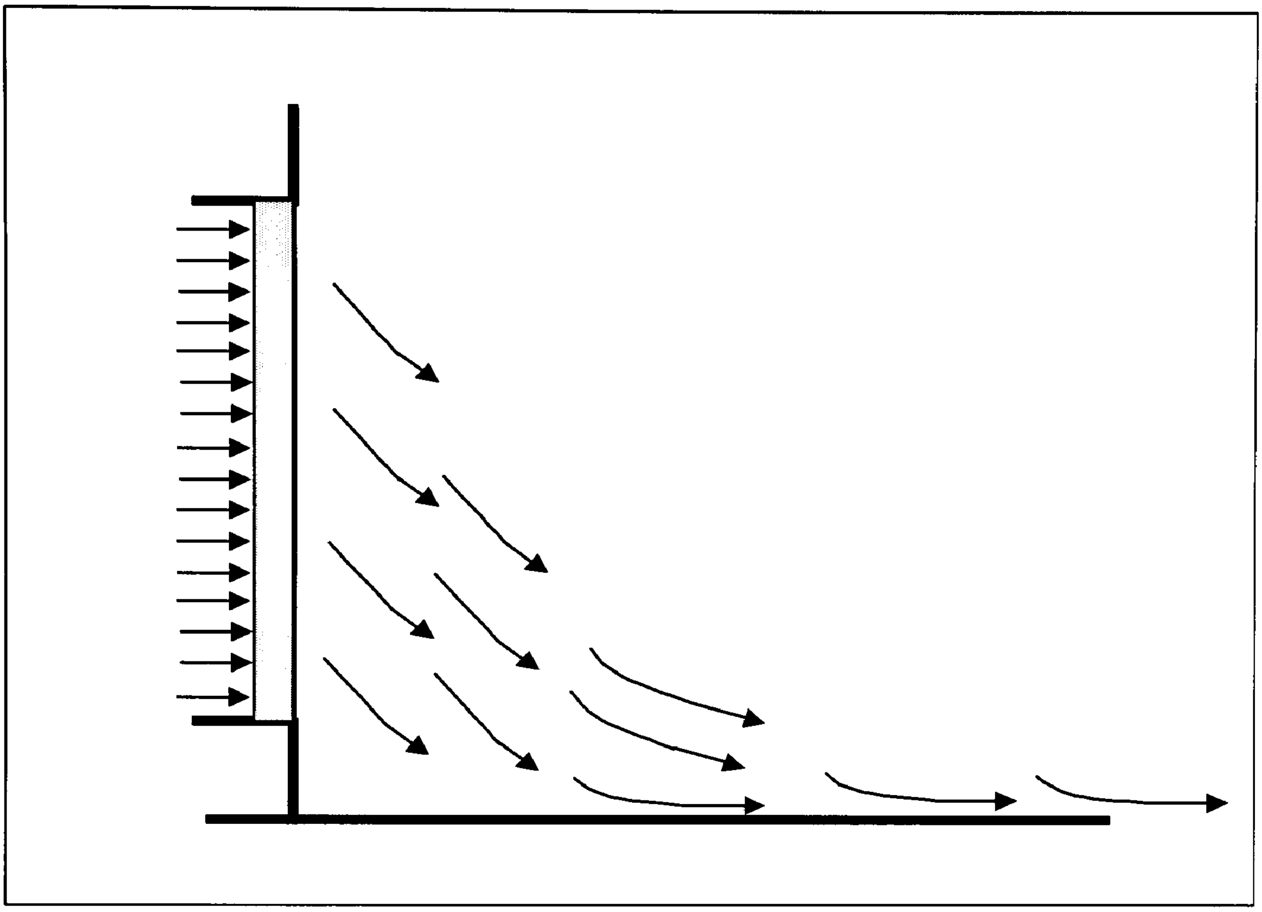


Figure 1.8 Flow pattern from a filter mat when the supply air is cooler than the room air.

Commercially available displacement ventilation diffusers incorporate either filter mats or a perforated panel to provide a low velocity discharge.

1.2.2.1 Discharge through a filter mat

When air is discharged through a filter mat diffuser, very little room air is mixed into the primary airflow. However, room air does become entrained at the boundary surface between the flow of air cascading towards the floor and the room air. The amount of entrained air is dependent on the turbulence in the supply air and the velocity gradient at the boundary surface.

The air velocity along the floor increases with the distance from the supply diffuser until it reaches a maximum, typically 0.6 - 0.8 metres from the diffuser. The velocity at floor level may be much higher than the face velocity, which is the complete reverse of the situation with diffusers used with dilution systems. The velocity profile at a distance of 0.5 m in front of a filter mat is shown in Figure 1.9.

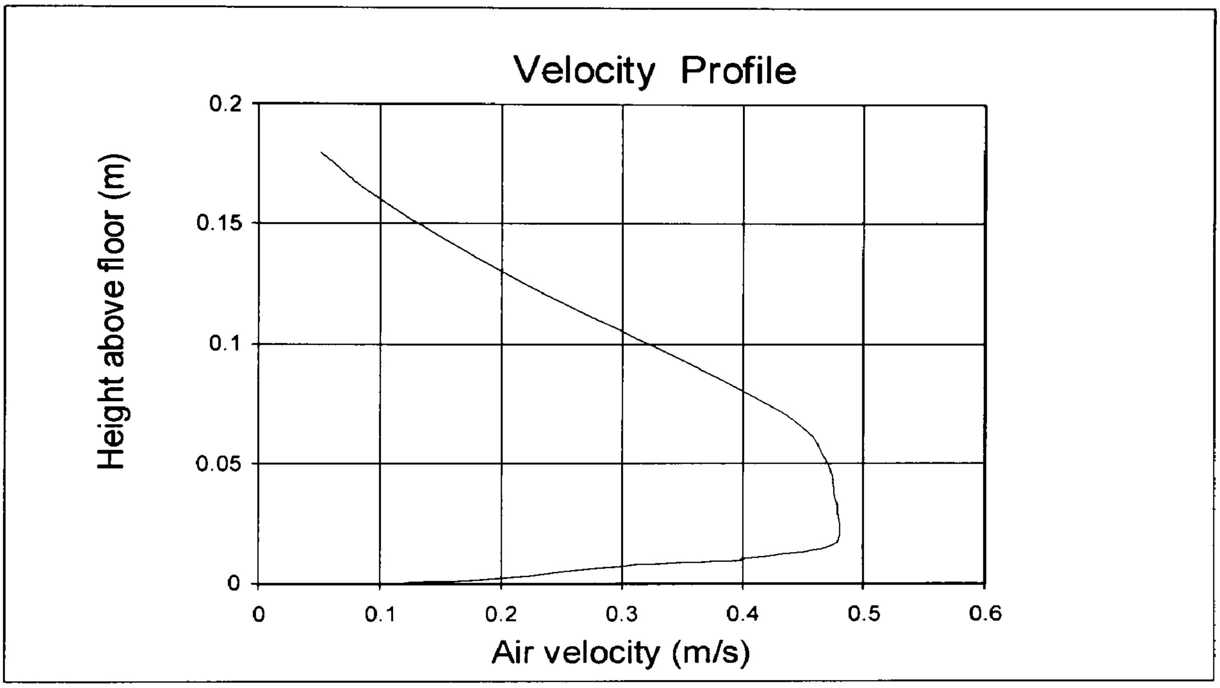


Figure 1.9 Velocity profile measured 0.5 m in front of filter mat diffuser (Source: Skistad 1994).

Data for air supply in Figure 1.9

Supply air volume flow rate =	0.062 m^3/s
Room air temperature – Supply air temperature,	
(Room/Supply air Δt) =	9.7 K
Height of filter mat =	0.9 m
Width of filter mat =	0.6 m
Front area =	0.54 m^2
Face velocity =	0.12 m/s

From Figure 1.9 it can be seen that the maximum velocity is occurring just above floor level and that it has increased by a factor of approximately 4 from the face velocity. This illustrates quite clearly the limitation of a filter mat diffuser, as the combination of low temperature and high velocity will cause discomfort to the occupants. Skistad (1994) proposes that to prevent this problem, a room/supply air temperature difference of no more than 1-2 K is used.

1.2.2.2 Discharge through a perforated panel

One way of reducing the cold draught is to induce room air into the supply airflow. The simplest method is the use of a perforated panel instead of the filter mat. When air is discharged through a perforated panel, room air will be entrained between the small jets created by the panel. This will rapidly raise the air temperature, and reduce the cascade effect, reducing velocity. This combination will reduce the draught risk. The volume flow rate with this type of diffuser is constrained by the noise produced by the small air jets.

1.2.2.3 The draught zone

When the supply air is cooler than the room air, there will be a draught zone close to all low velocity air supply units. An important design feature of a low velocity air supply unit is how far this draught zone extends.

As described in 1.2.1 above, with conventional diffusers the term "throw" is used to define the extent of the draught zone. For a low velocity supply unit, the air is not thrown so this term is not appropriate, and a draught zone length will be used instead.

Depending on the air temperature, the limiting velocity will be in the range 0.15 – 0.25 m/s (ISO 7730 1992).

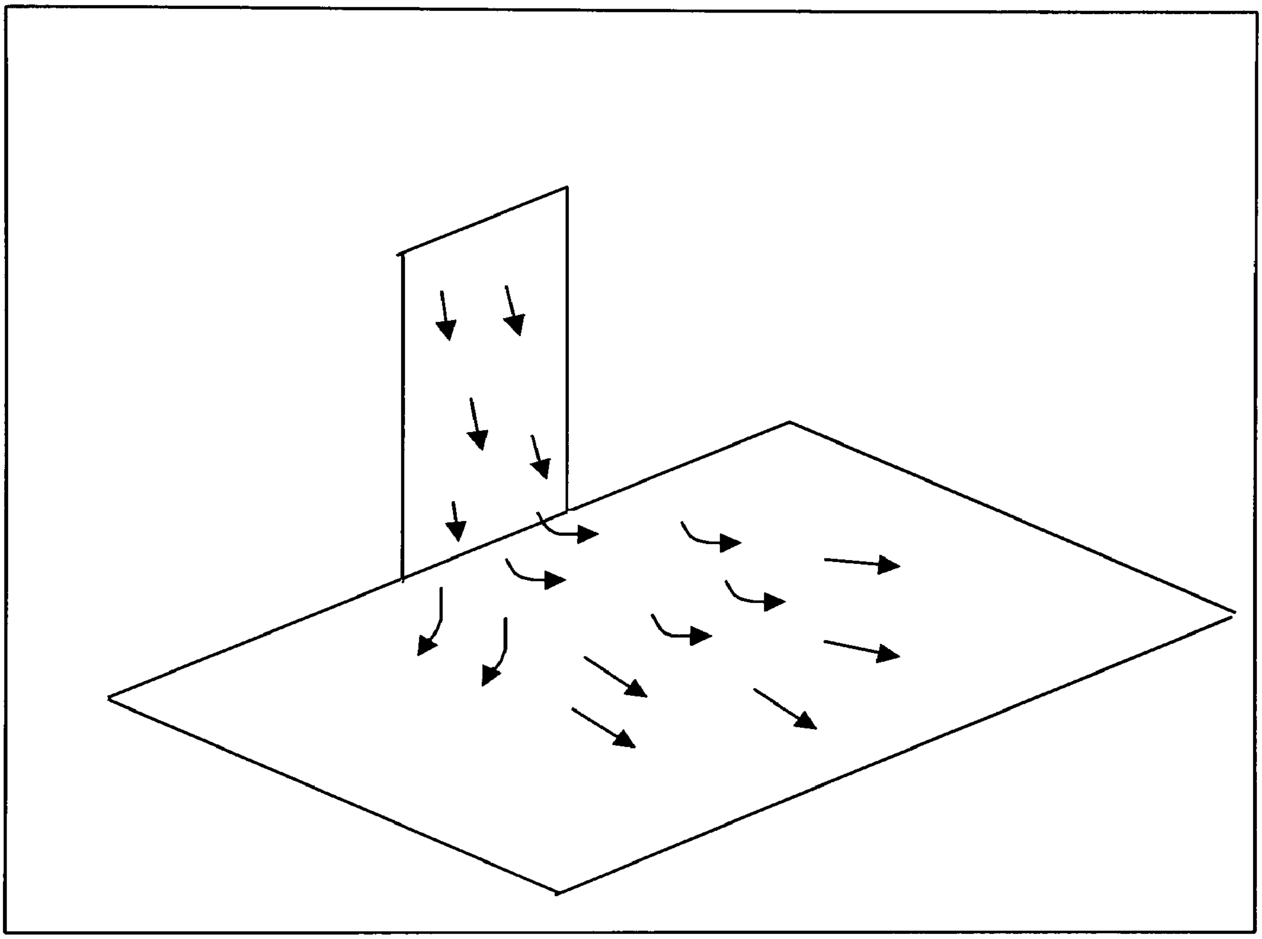


Figure 1.10 Draught zone in front of a low velocity air supply panel.

Chapter 2

Research Aims

And

Methodology

2.0 RESEARCH AIMS AND METHODOLOGY

2.1 Background to research project

The philosophy of the author in undertaking this project is to build on existing knowledge and skills established through industrial experience and subsequently developed through scholarly activity in delivering undergraduate education, in an area of personal interest, namely either low energy design or improving indoor air quality.

Incumbent on this is the need to work in collaboration with industry to ensure that any research that is undertaken addresses an area of current concern or uncertainty i.e. is close to market.

2.2 Hypothesis and aims

The potential benefits of displacement ventilation in terms of maximising air quality and energy conservation are not realised in practice. Furthermore, the use of ceiling mounted static cooling devices to supplement cooling has a detrimental effect on the air quality, and in many cases is not necessary.

The primary aims of the research project are:

i) To assess the effect on the indoor air quality of environments where displacement ventilation is deployed in conjunction with ceiling mounted static cooling devices.

ii) To identify and evaluate the performance characteristics of techniques for increasing the cooling capacity of displacement ventilation systems that preclude the use of ceiling mounted static cooling devices.

2.3 Research methodology

This research project is fundamentally a study of airflow and heat transfer in an enclosed space. Evidence can be obtained by three main approaches confirmed in the literature review as being experimental investigation, theoretical analysis and numerical calculation.

2.3.1 Experimental investigation

The most reliable information relating to indoor airflow and heat transfer is obtained by direct measurement. An experimental investigation should ideally be conducted at full scale to provide information on air velocity, temperature and pollutant distribution for a range of conditions. Such full-scale experimentation is expensive and time consuming, and not without problems. Care must be taken over the construction of the test facility and the calibration and location of instrumentation.

2.3.2 Theoretical analysis

Nearly all air flows encountered in a room are turbulent. Turbulence is defined in terms of irregularity, diffusivity, large Reynolds Numbers, three dimensional vorticity fluctuation, dissipation and continuum (Chen 1988). Turbulent flows cannot be defined exactly due to the fluctuating and interactive nature of the individual components such as velocity, enthalpy, pressure, and density. The iterative process required to develop the conservation laws in this situation becomes divergent rather than convergent, and assumptions and simplifications need to be adopted in order to obtain a mathematically acceptable solution.

This technique therefore requires validation of standard situations using the physical modelling technique in 2.3.1 above, and is very time consuming. With the development of powerful and relatively cheap microprocessors, this technique is now used to assist in the design of numerical modelling or computational fluid dynamics, CFD.

2.3.3 Numerical modelling (CFD)

Using microprocessors this method involves the numerical solution of a set of partial differential equations for turbulent flow and heat transfer. A range of proprietary software is now commercially available, and the speed of analysis makes this an attractive research tool. It must be remembered however that this is simply an automated development of the theoretical analysis described in 2.3.2 above and that care must be taken over assumptions made both by the operator of the software and by the software designer. For new situations, such software requires validation and often modification using full scale physical modelling as described in 2.3.1 above.

2.3.4 Selection of research methodology

The most reliable method for carrying out research into new methods of air supply is physical modelling, with the only restraint in the context of this project being the cost. The opportunity to use the test facility at BSRIA overcomes this restriction, making it the preferred method. Parallel research at BSRIA involved the development of computer models for the scenarios being physically modelled, providing the opportunity for the output from this research to be used to validate the computer modelling.

2.4 Preliminary research

Preliminary research was conducted to source two distinct areas of research activity, work published in academic and professional journals and conference proceedings, and work in progress as yet unpublished. To identify material in the first area the database search facilities in the Learning Resources Centre at the University of Glamorgan have been used, with the primary sources of useful information identified being ISBEDEX and BRIX. This has been subsequently supplemented with further research database searches carried out by the Library at BSRIA. Material for the second area of research activity could occur either because work was still in progress or because research was being undertaken by companies for their own commercial benefit, with no immediate intention of publication. Where relevant, authors of published work identified in the database search have been approached to discuss any ongoing aspects of their research. Through BSRIA it has been possible to identify and contact other researchers to discuss work in progress and as yet unpublished, including companies engaged in commercial research and development.

Chapter 3

Literature Review

3.0 LITERATURE REVIEW

3.1 Introduction

This chapter critically reviews current and previous research into the use of displacement ventilation in commercial offices with and without supplementary cooling devices. Where appropriate, reference is made to research identifying thermal comfort or air quality criteria that may be applicable in appraising any alternative displacement ventilation strategies to be considered.

Claims that displacement ventilation provides better air quality in the breathing zone, with a reduced energy requirement when compared with a mixed dilution ventilation system, are well documented (Chen Q 1991, Nielson P V 1993, Alamdari F et al 1994, Skistad H 1994).

A displacement system can achieve high ventilation effectiveness when the internal sources produce both heat and contaminants, as is the case with people and some office equipment. The vertical temperature gradient suggests that clean and contaminated air are separated, with contaminants collecting above the occupied zone, where they are effectively extracted.

In the belief that a better understanding of the mechanisms of displacement ventilation will reduce the level of uncertainty in the design of such systems, a wide range of research activity is being undertaken across Europe and in the Far East.

Additionally, research in other areas is highlighting the limitations of currently adopted comfort criteria in particular situations, and modifications to these are suggested. (Halliday S P et al, 1994; Croombe et al, 1992; Chow W K 1994; Mundt E, 1995). These new concepts need developing, as they will certainly prove relevant when considering the suitability of displacement ventilation for a range of applications. A particular drawback with current comfort criteria is that it makes no allowance for the desirability of short-term transient conditions.

In reviewing developments to date, three broad categories of research have been identified by the author:

i) to develop underlying theory with the aim of providing guidance for designers

ii) to establish the limitations of application, and the effects of cold surfaces on displacement ventilation

iii) to investigate the merit of combining displacement ventilation with static cooling, in order to provide offices that have high cooling loads with the benefits of displacement ventilation without overheating problems.

From the literature reviewed, a research model (shown below) was developed to map the activities of the range of researchers active in the field, towards the objective of providing reliable design advice.

3.2 Development of underlying theory

The approach to this area of work is varied. Some teams have concentrated their activity in one field of the model shown below, whereas some have worked holistically towards offering design advice.

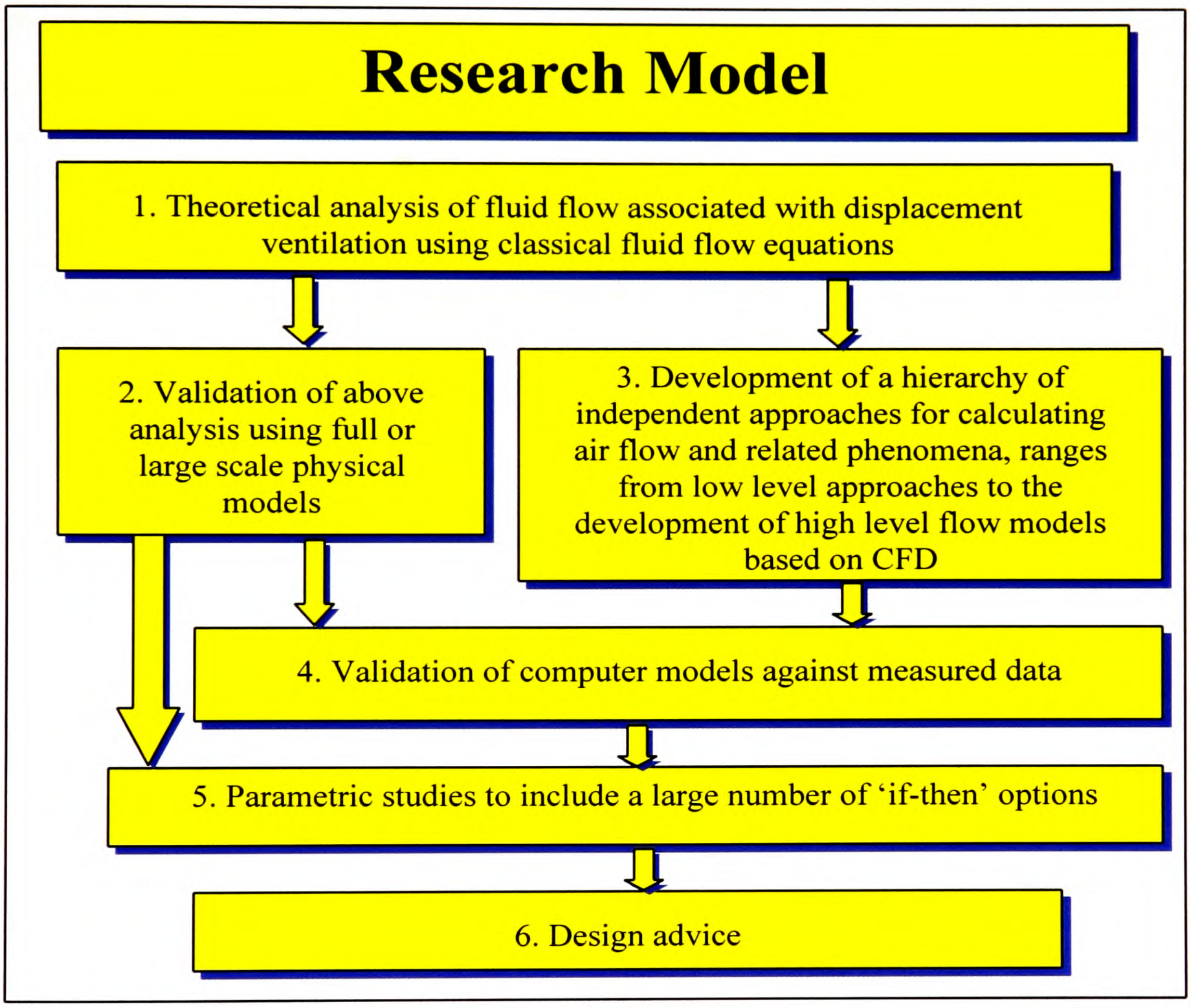


Figure 3.1 Research model

For instance, following work aimed at investigating the effect of thermal radiation from room surfaces on displacement ventilation flow using an experimental chamber (Li 1993), it was concluded that the results would be suitable for validating flow and radiation simulation. This is an example of research limited to one field, (2) in this model. Subsequently Li (1993) has proceeded to steps 4-6 using CFD simulation.

An example of the left-hand path through the model (1-2-5-6) is demonstrated by the work of Mundt (1992) who was not satisfied that earlier work had fully investigated the relationship between temperature gradient in a space and the convective flows from heat sources. This knowledge is essential to the successful design of displacement ventilation as the height of the interface between the "lake" of clean supply air and the contaminated displaced air is dictated by the flow rate of the plumes (Nielsen 1993). By detailed measurements incorporating a number of different heat sources, a model was developed to give values for convective flows in the presence of a temperature gradient. The work of Shankar et al (1995) follows the same path in developing numerical models and confirming their efficacy with physical modelling when studying the spreading properties of heat generated plumes.

The same route is followed in the work investigating the effect of movement of a heat source within an enclosed space, (i.e. a person walking across an office) Sandberg (1992). It was concluded that movement lowers the stratification height and causes oscillations of the interface. This was predicted by mathematical modelling, and confirmed by conducting tests on a scale model. These findings pose a question over the efficacy of displacement ventilation systems in buildings where the use is non-sedentary. However, a subsequent full scale modelling study has suggested that there is little disturbance to the stratification regime when someone is walking through the space (Akimoto 1995). For this study a survey was conducted in a working office to establish the frequency of walking activity which resulted in having an occupant walking from one end of the experimental room to the other every eighty seconds. The findings of this study may be more reliable than that of Sandberg (1992) as they are based on life sized modelling and experimentally obtained disturbance rates. However, the observations were made for an under floor supply through ventilating carpet tiles with an air supply rate equivalent to six air changes per hour, which is twice that usually supplied through the more commonly used wall/floor mounted metal bin diffusers. It may be surmised that this higher flow rate has produced a more robust displacement regime than would be achieved by diffusers supplying lower flow rates.

In addition to these findings, a view is put forward by Wyatt (1993) that a thin "personalised" boundary layer of fresh air is maintained in the breathing zone despite the lowering of the interface; this is supported by other work on convective flows from heat sources (Mundt 1993). Bjorn (1995) when studying the effect of the close proximity of two heat sources found that they maintained separate plumes rather than combining, which adds weight to this view. Etheridge and Sandberg (1996) provide a comprehensive discussion of this issue in their book "Building ventilation –theory and ventilation".

In practice it is likely that concerns over the effect of movement of occupants on the displacement regime will be overshadowed by concerns over the airtightness of the building. If the quality of construction of the building is poor resulting in high infiltration rates, there will be disturbance to the displacement flow. This phenomenon will not cause such a problem with mixing systems where such leakage may even assist the dilution process, but with the delicate nature of displacement as identified above such external disturbance is undesirable. The standard of airtightness of construction in the UK has been found to be poor and there are proposals to introduce air tightness standards into the Building Regulation process to improve this situation (Brundrett 1997).

When undertaking modelling to predict performance as identified in step 3 of the model, the simultaneous transfer of heat and mass create complex relationships. The problem for the modeller is to keep the model as simple as possible without losing accuracy. This is usually achieved by analysing dimensionless characteristics such as the Archimedes and Rayleigh numbers that can indicate the relative importance of the physical parameters. This will then allow assumptions or simplifications to be made with confidence that there is no significant effect on the accuracy of the result.

Tinker and Woolf (1994) have investigated the effect of making these environmental parameter assumptions when modelling to predict environmental conditions in a space. Their technique was to compare experimental data from a quarter scale model with results from a dynamic thermal model and CFD simulation. The work is still on going but they have already provided useful data for other researchers. They also identify that if modellers included their environmental parameter assumptions when publishing results, comparisons could be made with greater confidence.

Examples of the "total concept" approach incorporating all six stages of the above research generally include the verification of a CFD package as a design aid.

This was the philosophy of the research being undertaken on displacement ventilation at the BSRIA Microclimate Centre, (Alamdari et al 1994), where a combination of site measurements and computer modelling was used to establish the variation of room air temperature with height. Alamdari (1994) considered the CFD modelling approach sufficiently reliable to investigate further the problems of floor level obstructions and down-flow from cold surfaces.

Holmberg et al (1992) also turned to computer modelling to demonstrate that a horizontal displacement effect could be achieved without help from thermal forces. This approach was followed because the air velocities in the test room were found to be too low to measure experimentally. A similar conclusion was made by Alamdari et al (1994).

Filleux et al (1994) have focused on the production of a design nomogram for thermally induced displacement ventilation without chilled ceilings, although it is increasingly the case that displacement ventilation is used in combination with chilled ceilings.

3.3 Limitations of application

A number of claims are made about the amount of cooling that can be handled by a displacement ventilation system: 25 W/m^2 Sandberg (1989) and Niu (1993), 70 - 100 W/m^2, Konegi et al (1991) and 40 - 50 W/m^2, Twinn (1994) are examples that show that there are conflicting views. This may be the reason that designers are looking for additional cooling via "static" devices, to reduce the risk of potential overheating. Of particular concern when displacement ventilation is used, is the draught risk and thermal discomfort at ankle level. The design intent of keeping the supply air temperature slightly below the room air temperature, combined with the need to supply at low level with resulting air movement across the floor, imposes severe restrictions on air volume flow rates, which in turn limits cooling capability as identified above. CFD analysis has been utilised to show that by limiting the temperature difference, or the proximity of occupants, discomfort may be avoided (Gan 1995). Gan (1995) studied a number of permutations and concluded that with a supply air temperature of 18 ^oC and a supply air velocity of 0.2 m/s, occupants would need to be 3 m away from the diffusers. Also, if velocities can be limited to less than 0.1 m/s, the degree of thermal discomfort becomes solely temperature dependent, and if supply air temperature is increased to 22 ^oC thermal comfort will be acceptable. To comply with these requirements the cooling capacity of the displacement supply system would be further reduced, or significant areas of the occupied space would be unsuitable for sedentary activities.

There are also conflicting claims over the real air quality benefits associated with displacement ventilation. Cox et al (1993) measured a ventilation effectiveness of 1 in a test room, equivalent to a good dilution system. Guntermann (1992) identified an improved air quality, at a height of 1.0 - 1.4 m near heat sources, but also that air quality is detrimentally affected when the supply diffuser is greater than 0.8 m high as the strong downdraught created drives air back towards the diffuser (1995). Laurikaiven (1991) states that with displacement ventilation, air quality may be 3 times better than with a dilution system with the same air flow rate. Breun (1992) links relative improved air quality with increasing air change rates when comparing displacement with dilution systems.

Although the findings of all four researchers may be accurate and correct, the apparent conflict may simply be due to the fact that they are reporting different situations. Sateri (1991) identifies the need to measure air quality in the breathing zone. With a mixing system (assuming perfect mixing), the measurement of contaminants can be taken anywhere in the room to calculate ventilation effectiveness. With a displacement system the level of contaminant is very variable with location and if the effectiveness is to reflect the experience of the occupant, it is only the breathing zone that is relevant. Use of the local air quality index (AIVC 28-2 1991) appears to address this problem as it provides a measure of air quality at a point in a space. It is suggested that very high values are achievable with displacement ventilation. However the measurement of concentration of contaminants is by laser particle counter so the point is actually a horizontal "core" of air in the space, and this will not always be in the breathing zone. Kruhne (1995) used this technique to study the effectiveness of displacement ventilation for point sources and uniformly distributed sources of contaminants. Kruhne concluded that the concentration levels closely followed the temperature profiles for uniformly distributed sources, whereas this was not the case for the point sources. In all cases however the results were better than for a room with mixing ventilation.

Following measurements in an experimental test room, Roulet (1993) also warns of the problems of using ventilation effectiveness when comparing the performance of displacement systems and mixing systems. The project compared a number of ventilation and cooling strategies including displacement ventilation with and without a chilled ceiling, and mixing ventilation with slot and vortex diffusers. Roulet identified that the ventilation performance of the displacement system was reduced when the chilled ceiling was in use, particularly when the use was intermittent.

Säteri (1991) and Koganei et al (1991) both make reference to the possibility of a problem with CO_2. As it is denser than air, there is a possibility of it being trapped in neutral buoyancy with a displacement system. If this were to occur at the breathing zone height this would be very unsatisfactory. It is more likely however that neutral buoyancy entrapment will be a problem with small airborne particles.

3.4 Previous work on displacement ventilation with static cooling

A number of researchers (Neilson P V 1993, Alamdari F et al 1994 and Koganei et al 1991) have suggested that downward convection due to cold surfaces such as windows or cold external walls will seriously disrupt the buoyancy driven displacement flow. This is considered a sufficient disturbance to break down the stratification boundary, mixing air from the contaminated upper zone with the clean lower zone, negating the main benefit of the displacement system.

Kruhne (1993) has concluded that displacement ventilation in combination with cooled ceilings, that may be used to supplement the limited cooling ability of the conventional displacement ventilation system, does not always have an advantage over mixing ventilation where air quality is concerned, but that thermal comfort conditions are achieved. This conclusion is supported by the physical modelling work carried out by Kulpmann (1993).

Using the local air quality index (AIVC 28-2 1991) as the criteria Fitzner (1995) established than when the proportion of the total cooling load provided by a chilled ceiling (panels) increased above 60%, the air quality was no better than with a mixing ventilation system.

Recent physical tests (reported in Chapter 5) carried out by the author at BSRIA support this finding. Using a model room facility incorporating a displacement ventilation system with a chilled panel ceiling, smoke visualisation tests were carried out, releasing test smoke above the false ceiling. It was observed that the smoke rapidly contaminated the room. Closer inspection revealed that the smoke was falling through every extract grille, and every unsealed joint in the ceiling.

This indicates that the reverse side of the chilled panel is cooling the air in the ceiling void, and that there is insufficient pressure difference between the room and ceiling void to overcome the resulting negative buoyancy.

Although this recirculation effect enhances the heat exchange from the chilled panel, it is destroying the air quality characteristic of the displacement ventilation system. The work at BSRIA concludes that where static cooling devices are used in conjunction with displacement ventilation systems, care should be exercised in the specification and construction of the ceiling, (i.e. sealed joints), to ensure positive air flow from room to ceiling void (Alamdari 1995).

Additionally, work carried out by Taki et al (1996) indicates that the temperature of the chilled water is influencing the displacement flow increasingly as it reduces from 21 ^{o}C, and that with a ceiling temperature of 14 ^{o}C, displacement flow is completely destroyed.

Despite these findings there is significant research activity (Alamdari et al 1994, Wyatt 1993, Prochaska et al 1992, Busweiler 1993) into, and commercial application (Thomas 1994, Davies 1994, Bunn 1994, Alamdari 2000) of, static cooling with displacement ventilation to counter the risk of thermal discomfort due to high heat gains. This activity seems to be driven by the over-riding need to reduce the design risk of overheating which is easily perceived by the building occupants, at the expense of air quality which is less tangible. The issue of measuring and specifying air quality standards is in not even agreed by designers and is the subject of ongoing unresolved debate (Lunau 1993, Oseland 1993, Aizlewood 1995, Building Services Journal 1997).

This research activity could arguably be overlooking current design philosophy in two major respects in addition to the air quality concerns. The positioning of static cooling at ceiling height introduces a false or lowered ceiling with the following consequences.

- the creation of a barrier to building fabric thermal storage by ceiling slab.

- the depression of high temperature zone towards the occupied zone.

The use of night cooling for example may be optimised by the exposure of the building mass. The emergence of this technique is exemplified by the work of Martin (1995) which identifies control strategies for the technique. Mixed mode ventilation strategies promoting the use of building thermal mass are being adopted by leading practitioners (Bordass 1994 and 1996, Arnold 1995 and 1996), and encouraged by the Best Practice Programme of the Department of Environment Transport and the Regions (New Practice Final Report 106, 1998).

There have been product developments that would allow the use of suspended ceilings whilst still utilising thermal storage. An example of this is reported by Barnard (1998) with the use fabric connected ductwork, but there is no evidence of this being widely used.

Ma (1994) proposes an alternative method of applying static cooling to the displacement ventilation system, by supplying chilled water to the heating system radiators, during periods when cooling is required, on a two pipe changeover system as may be adopted with fan coil systems. As demonstrated by CFD modelling, this will provide some cooling effect without the disadvantages identified above, and as the radiators are located low in the pool of clean air, their downward convection should not significantly reduce air quality and may in fact assist the displacement flow. This system also has cost benefits over a chilled ceiling, but further work is required as there is little information on the cooling performance of radiators, or the ratio of radiant to convective output.

The use of radiators for cooling has also been proposed for warm humid environments such as are experienced in Japan (Hirayama 1996). In this climate the use of chilled ceilings are particularly restricted by needing to operate above the high dew point temperatures experienced, limiting the cooling capacity accordingly. The use of radiators instead would create a cooling and dehumidifying device as condensate could be collected at the base and removed to drain. Using an environmental test chamber, Hirayama (1996) assessed the performance of such a system. He concluded that to achieve satisfactory cooling rates with the relatively small temperature differential, larger radiators would be required allowing a smaller temperature differential when in heating mode. This would require a carefully integrated design approach to ensure successful operation.

A concern identified over the use of chilled ceilings is the risk of condensation on the cold surfaces, which may form droplets that could fall into the occupied space (Martin 1997). This phenomenon is anticipated where fan coil units are used, and drip trays are installed to deal with these droplets. It is the experience of the author, that undergraduate building services engineers are encouraged to design the fresh air supply system so that the relative humidity in the occupied space is low enough to prevent such condensation. This is to avoid dependence on the drip trays, which are notorious for becoming blocked and causing problems. The same design principles can be applied to the fresh air (displacement) supply for chilled ceilings, but the success of the strategy is more critical as drip trays cannot be used with chilled ceilings.

Laboratory work has been carried out by Martin, (1997), to determine the circumstances and the extent to which condensation occurs on chilled ceiling panels and beams, and the effectiveness of various control strategies designed to prevent it. The conclusions indicate that it is possible to avoid the formation of condensation with no loss of cooling performance, but subject to a high energy penalty as the supply air humidity should be scheduled to room temperature to maintain the room dewpoint condition. Alternatively, control of the chilled water flow temperature will be equally effective. It is more energy efficient than using supply air dehumidification control but will result in a loss of cooling effect.

Field trials that are reported by Butler (1997) investigated the effectiveness of anti condensation measures in four buildings with chilled ceilings during the summer of 1996. Three of the buildings used dehumidification of supply air, and one turned off the chilled water during risk periods. The conclusions from this study suggest that there were no condensation problems reported in any of the four buildings during the test period, but that further study was required. This study is analysed further in Chapter 7.

The use of displacement ventilation to provide segregation of building occupants from sources of pollution is identified by Kolokotroni et al (1995). This work assessed the problem of separating smokers, arguably the worst pollution source that may be encountered in non-industrial buildings. The opportunity to tackle this problem in leisure buildings, such as public houses, using high volume flow rate displacement ventilation is identified by Geens (1998).

Chapter 4

Rationale For Research

4.0 RATIONALE FOR RESEARCH

From the literature review carried out, four broad categories of research have been identified. The research requirements are:

i) to develop the underlying theory relating to displacement ventilation with the aim of providing guidance for designers.

ii) to establish the limitations of the application of displacement ventilation to the environmental control of commercial buildings.

iii) to assess the merit of combining displacement ventilation with static cooling in order that offices with high heat loads can enjoy the air quality benefits of displacement ventilation without overheating problems.

iv) to assess methods for increasing displacement flow ventilation flow rates to maintain comfort conditions.

At the time the author began collaboration with BSRIA, work in the last two categories was in progress to establish the performance of chilled ceilings in combination with displacement ventilation. As previously identified in the literature review (Section 3.4), the subject of the detrimental effect of cold surfaces such as windows and external walls was causing concern amongst a number of researchers. As the chilled ceilings were presenting a cold surface to the room air, the author surmised that their use would significantly interfere with the intended buoyancy driven ventilation system. Consequently, this was investigated at the initial stage of the experimental programme.

The tests in progress at BSRIA involved monitoring the performance of both chilled beams and chilled panels in combination with floor mounted perforated semi-cylindrical displacement diffusers. The chilled beams (finned convectors in principle) and the chilled panels, were both installed in the test room ceiling. The test facility is described fully in Chapter 5.0 – Feasibility Study and Analysis. The general appearance and layout of the room can be seen in the smoke visualisation sequences in Section 4.1 below. The rationale for this project was that earlier work at BSRIA had confirmed that with diffusers currently in use, displacement ventilation alone provided only limited cooling capacity of the order of 20 W/m^2 and higher cooling loads would require some form of supplementary cooling. Chilled ceilings were being investigated as a possible solution to this problem. The BSRIA test programme included cooling loads up to 100 W/m^2 to encompass the range of likely situations in modern commercial buildings.

4.1 Smoke visualisation

To test the detrimental effect theory, (i.e. that chilled ceilings significantly interfere with the buoyancy driven displacement ventilation system), it was decided to use smoke visualisation techniques recorded using VHS video equipment. Images captured from these video recordings are shown in Figures 4.1a - 4.9d. Smoke visualisation involved the release of a neutral density smoke into the test room at the desired locations, and by observation provided a graphic method for determining the movement of air streams in the test facility. This technique was already in use by the BSRIA team to enable a qualitative analysis of airflows from the displacement diffusers at floor level, but had not been introduced at ceiling level to check the possibility of a detrimental effect being produced by the ceiling. The technique is also reported in work carried out at the test laboratory of EA Technology (Dickson 1994).

4.2 Video capture evidence

The detailed video evidence of these smoke visualisation tests is presented and described below. The tests at BSRIA were recorded on VHS videotape and subsequently converted using image capture software at the University of Glamorgan to provide these images.

4.2.1 Test room with Chilled Beam devices in the ceiling.

The sequence of Figures 4.1a – 4.1d shows the test room with the chilled beam mounted along the centre line of the ceiling. This sequence shows the introduction of smoke into the ceiling space, just above the chilled beam. The chilled beam and the displacement ventilation supply system in the room are both in operation. The sequence shows a time period of 62 seconds. In this time, the powerful downward convection current from the chilled beam has driven the contaminated (exhaust) air from the ceiling space down to floor level, (against the general upwards movement of the air in the room from the displacement supply diffusers), and back up to the ceiling. The whole room has quickly become obscured by smoke confirming that the displacement regime has been completely disrupted and replaced with a mixing regime.

The sequence of Figures 4.2a – 4.2d shows the room air distribution pattern of air supplied through the displacement ventilation diffusers. For this and subsequent sequences the chilled beams have been turned off so that the displacement regime can be visualised without downdraught interference. The sequence shows the air entering through the diffusers, sinking to the floor and spreading across the floor showing no tendency to mix with the air already in the room.

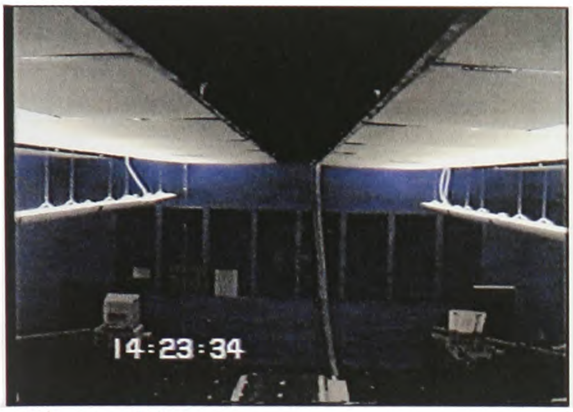


Figure 4.1a

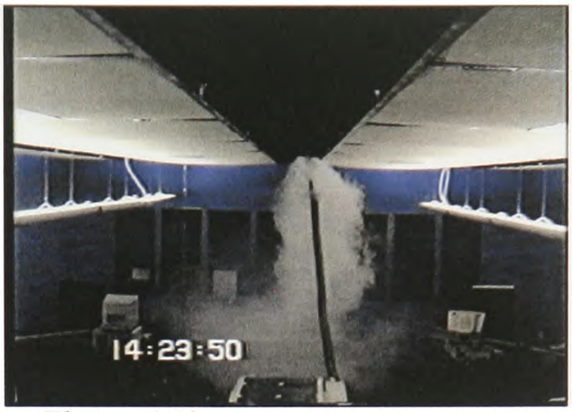


Figure 4.1b

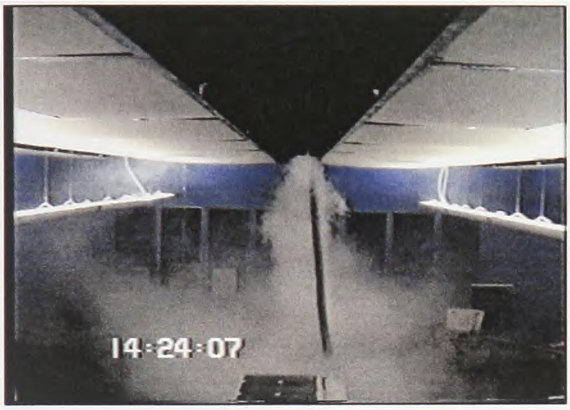


Figure 4.1c

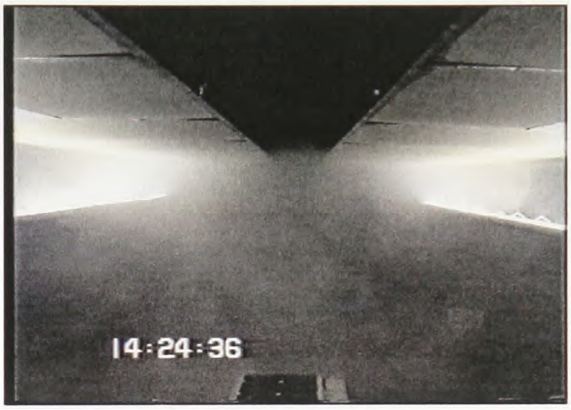


Figure 4.1d


Figure 4.2a

Figure 4.2b

Figure 4.2c

Figure 4.2d

This sequence shows the measurement grid marked out on the floor, the workstation equipment, and the heater mats simulating the heat output of the photocopier.

The sequence of Figures 4.3a – 4.3c shows a clean air supply from the displacement diffusers "containing" a contaminant, (smoke), being generated at the centre of the room. There is no evidence of the contaminant encroaching into the "clean zone".

Figure 4.3a

Figure 4.3b

Figure 4.3c

The sequence of Figures 4.4a – 4.4d shows the subsequent development of stratification zones with a clear boundary between clean and contaminated air evident at around desktop level. This matches the classical theory of displacement ventilation, which predicts this distinct separation. To satisfactorily control temperature and by implication, air quality in the occupied space, this interface needs to be above head height.

Figure 4.4a

Figure 4.4b

Figure 4.4c

Figure 4.4d

The sequence of Figures 4.5a – 4.5b shows the individual plumes developed by the simulated occupants. The smoke traces are more evident on the original video than in these stills, as the motion creates contrast making the movement more obvious.

Figure 4.5a

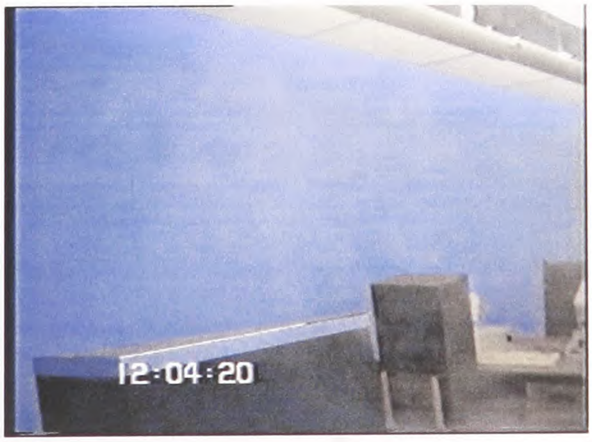


Figure 4.5b

4.2.2 Test room with Chilled Panels in the ceiling.

The sequence of Figures 4.6a – 4.6c shows the introduction of smoke above the suspended ceiling housing a number of chilled panel static cooling devices, with the panels on and the displacement ventilation system providing 3.5 air changes per hour. The sequence shows that despite insulation on the back of the panels, air is sufficiently cooled to drive it downwards through any gaps in the suspended ceiling. This is occurring with sufficient momentum to overcome the displacement flow and almost reach the floor.

Figure 4.6a

Figure 4.6b

Figure 4.6c

Figure 4.7 shows smoke that has been released above the suspended ceiling cascading over the edge of the ceiling panel, where there is a small air gap. This air appears to have sufficient velocity to generate a Coanda Effect, as the air is attracted to the wall.

Figure 4.7

The sequence of Figures 4.8a - 4.8c shows the same effect as previous sequences, with the smoke being introduced at a different point above the ceiling.

Figure 4.8a

Figure 4.8b

The sequence of Figures 4.9a – 4.9d shows smoke being released within the room, but close to the point of extract to confirm that the ceiling space was at a negative pressure relative to the room, and that air was being extracted from the room. The duration for this sequence was 8 minutes and 5 seconds. During this time, the quality of the air in the room deteriorated significantly with smoke concentration increasing to a degree that is readily discernible on the captured images.

Figure 4.9a

Figure 4.9b

Figure 4.9c

Figure 4.9d

4.3 Analysis of video evidence

4.3.1 Test room with Chilled Beam devices in the ceiling

The sequence of figures 4.1a – 4.1d confirms that when the limited cooling effect of conventional displacement ventilation systems is supplemented with a chilled beam cooling system, the downward convection plume effectively destroys the displacement flow regime and re-introduces contaminated air into the room.

In demonstrating the high air volume flow rate through the chilled beam, this sequence confirms that the chilled beam provides a good room air distribution pattern for a mixing system without fan assistance, making it more energy efficient than the very similar fan coil units. Draught discomfort however, would be experienced immediately below the beam. This was found to be the case in an undergraduate study, supervised by the author, of the NCM building in Cardiff Bay which is equipped with displacement ventilation and chilled beams. (Ardi 1996).

The sequence illustrated by Figures 4.2a – 4.2d shows that the location of displacement diffusers is not critical because within the 30 seconds of the sequence, the new supply air has spread completely across the space. This characteristic will make the integration of these diffusers much easier as there is no need for a regular or room symmetrical array of supply diffusers to ensure good room air distribution as there is with supply diffusers for a mixing system of ventilation.

The sequence illustrated by Figures 4.3a – 4.3c shows how effective displacement ventilation is, in isolating contaminants within a space where local exhaust ventilation is not practicable.

The clear vertical stratification shown in the sequence of Figures 4.4a – 4.4d confirms that a displacement flow regime is established, but that the supply volume flow rate (3.5 air changes per hour) is insufficient for the thermal load in the room. This confirms the need for supplementary cooling, but with reference to sequence 1, it has been shown that supplementary cooling by chilled beam destroys the displacement flow regime and is therefore counterproductive and unsatisfactory.

The individual smoke plumes from the simulated occupants shown in the sequence of Figures 4.5a – 4.5b demonstrate the effectiveness of a displacement flow regime in removing point sources of heat and contamination. This is a valuable characteristic in situations where individual occupants or office equipment are producing contaminants that would bother other occupants. Locations where smoking is permitted would be an example of this, for example bars and restaurants where staff need to be protected from exposure to tobacco smoke. Ozone producing office equipment would be another example.

4.3.2 Test room with chilled panels in the ceiling.

The sequence of Figures 4.6a – 4.6c demonstrates that although the downward plume is weaker than that for the chilled beam, it is still significant. At the time these trials were conducted, the research team at BSRIA believed that this configuration was safe with respect to this problem, and subsequently published an article to emphasise this newly identified risk (Alamdari 1995).

The findings revealed by Figures 4.6a – 4.6c are confirmed by Figure 4.7 which emphasises the conclusion that to avoid this problem when chilled panels are incorporated in a suspended ceiling, great care is required over the detailing of joints.

Given the dramatic nature of the findings of this test, and due to concerns that smoke had been introduced at a point that coincided with a "freak" weakness in the ceiling grid, the smoke was introduced at the opposite side of the ceiling. The sequence of Figures 4.8a – 4.8c shows that the first result was not a freak, and that smoke was still being discharged with sufficient momentum to reach the floor.

Still looking for other contributing factors, and despite the fact the room had been commissioned to confirm supply and extract rates at the outset, it was considered necessary to confirm positive flow from room to ceiling void. This was carried out by releasing smoke in the room but close to the extract grilles. This procedure illustrated in Figures 4.9a – 4.9d confirmed that this positive flow was occurring which ratified the conclusion already drawn. As further confirmation, smoke was still being returned to the room.

The smoke which, given its method of introduction, was now more diffuse within the ceiling space, no longer appeared as clearly visible plumes. However, it is clear from the sequence, that after a period of 8 minutes, the room had become significantly smoke contaminated. This is a truer reflection of how this system would lead to poor air quality in the occupied space when the chilled panels were in operation.

4.4 Summary of video evidence findings

As can be seen, in Figure 4.1a, the downward convective cold air plumes from the chilled beams transported the smoke to a level well within the occupancy zone. A number of release points were tried, both between the beams and directly below the convective fins of the beams and the convective downward plumes were consistently observed to penetrate to below the level of the furniture in the room. Irrespective of the release point, 5-10 minutes after release, smoke was uniformly distributed throughout the room. This mixing was noted to be more vigorous at higher load levels with consequently higher chilled beam output levels. Observations were conducted for room cooling loads in the range 40 – 80 W/m^2.

When the tests were repeated for the chilled panels, it was anticipated that the downward airflow would be much weaker as these units were primarily radiant in output. In fact the downward flow was very similar to that observed with the chilled beams. Close scrutiny revealed that there were a number of opportunities for strong downward convection plumes to develop. Firstly, air within the room was being cooled in contact with the cold panel, and was moving slowly in a lateral direction until it reached the edge of the panel. At the edge of the panel, as the panels were not an airtight fit in the ceiling, an opportunity for vertical airflow arose, and due to the low temperature of the air, this was observed to be strongly downward, Figure 4.7. Secondly, although the upper surfaces of the panels were insulated, sections of the connecting pipework were not, and a pool of cooler air was being created above the ceiling. It was observed that at every opportunity, air was leaking from the ceiling void into the room, Figures 4.9a – 4.9d.

These findings were acknowledged by the BSRIA team and included in the project report (BSRIA Report 77720/1). This report confirmed that thermal comfort was good when high heat loads were handled by displacement ventilation with static cooling devices in the ceiling, but highlighted concerns in respect of the findings of the smoke visualisation exercise. They indicated that some of the problems with the chilled panels could be overcome with better insulation and a better sealed ceiling, but that further research was necessary, (Alamdari 1995).

The problem with this observed downward convection is best illustrated by considering the operational sequence for such a system as follows. At the beginning of a typical working day, the ventilation system will be providing a good displacement regime with contaminants in the space rising to be extracted through the ceiling void. This will result in the air quality in the ceiling void being significantly poorer than in the occupied space. As time passes, the cooling requirement will increase due to casual gains and solar gains, and the limited ability of the fabric to absorb these gains. At some point, the limitation of the displacement ventilation to deal with the cooling load will be exceeded, and the environmental control system will bring the chilled ceiling into operation. This, as discussed above, will result in the dirtier ceiling void air being dumped back to floor level and ultimately re-mixed with the room air. The air quality benefits are therefore only available to the occupants for the periods when the chilled ceiling is not operating.

4.5 Solutions considered

These findings focused the project on investigating alternatives to static ceiling devices to extend the application of displacement ventilation to situations where the cooling load is greater than 20 W/m^2. It was felt that a system, which at best was heavily reliant on the quality of the site installation, was fundamentally flawed.

From the literature review, a number of possibilities were considered. The work by Ma (1994) suggested using existing heating system radiators as chilled panels in the cooling season. The surface areas involved would be smaller than available with ceiling devices, and therefore a smaller contribution to cooling would be available. Any downward convection currents would be at low level within the pool of supply air, and would not seriously disrupt the floor to ceiling airflow regime. According to Ma, (1996) the published work was based entirely on computer modelling, and Ove Arup were actively looking for a client willing to adopt the concept for field trials. This, coupled with the information that BSRIA intended to use their existing radiator test facility to produce design output data for radiators using chilled water, meant that there was no opportunity to investigate that option further.

A paper by W Chow (1993) prompted another possibility. In this paper, the results of experiments on the human response to draughts at elevated temperatures were reported. The paper concluded that the occupants of buildings prefer to have a sense of air movement when the room temperature is high. Consequently, the Fanger criteria for comfort needed modifying to accurately predict the percentage dissatisfaction at higher temperatures. Although this work was done in the context of the Hong Kong climate, and not with displacement ventilation in mind, the principle identified could be useful. The limitations on the cooling capacity of current displacement ventilation systems are noise and draught risk related.

The basic cooling load equation is given by:

$$Q = mc_p\Delta t$$

Where,

Q is the cooling load (kW)

m is the cooling air mass flow rate (kg/s)

c_p is the specific heat capacity of air (at constant pressure) (kJ/kgK)

Δt is the supply/room temperature differential (K)

Given that the supply temperature is typically limited to 19 °C (BSRIA TM2/90), the opportunity to increase the cooling ability of the system is limited by the ability to increase the mass flow rate of the supply air. It is in trying to increase this flow rate that noise or draught problems are encountered. The problem can be overcome simply by providing more or bigger diffusers, but costs and aesthetics limit the extent of that strategy as a solution. The work of Chow suggests that a purge cycle may be acceptable in dealing with higher cooling loads. This would operate on the following principles:

i) A room air distribution system would be designed for a cooling load of 20W/m^2, but the air supply system, (fan and ductwork), would be designed for a higher load.

ii) In operation, when the room temperature reaches the top end of the comfort range, at perhaps 27 or 28 ^{o}C, a purge cycle would be initiated with the maximum flow rate being supplied. If the displacement flow was maintained, the high temperature air could be displaced in a matter of minutes.

iii) The consequent draught and noise problems would be transient and therefore possibly acceptable to the occupants.

Although promising, the number of questions to be answered and the nature of the testing required were beyond the resources of this project. The findings of this thesis show that such a technique would not be required at least up to cooling loads in the order of 50 W/m^2. This may justify further work, if higher cooling loads are to be treated.

A range of tests were identified which explored the problem of dealing with high heat gains, employing existing diffuser technology to establish whether there was any scope for extending currently accepted thresholds. The basis of the hypothesis underlying this research is that it should be possible to introduce a higher air change rate to deal with higher heat loads, without causing occupant discomfort. Tests by the author were carried out using the standard type of displacement diffuser as traditionally used in industrial applications. The preliminary results indicated that modest improvements could be achieved.

An earlier BSRIA unpublished research project, (Bennett 1994), had used a diffuser that produced a 'draught free' supply to solve a ventilation problem in the sleeping accommodation on submarines. This diffuser was a polyester-based 'textile' diffuser of a weave density designed to permeate large air volumes without creating noise or draughts. Although the submarine application was entirely different from the situation under consideration here, the textile diffuser principle seemed to offer a possible solution. A feasibility study to investigate this possibility further was proposed. Enquiries with a manufacturer of the textile diffuser, Dean and Wood Ltd confirmed that their diffuser had not been used for low level displacement ventilation applications (Waumsley 1994). They were very interested in the research programme that was being proposed, and volunteered to manufacture and supply any diffusers that would be required to carry out tests. Full scale trials of a textile diffuser in parallel with the BSRIA test programme for chilled ceilings with standard displacement diffusers were undertaken so that a performance comparison could be made. This trial is described in Chapter 5.0.

Chapter 5

Feasibility Study and Analysis

5.0 FEASIBILITY STUDY AND ANALYSIS

The experimental work reported in this chapter comprises a feasibility study to assess the effectiveness of textile diffusers at increasing air flow rates for displacement ventilation performance.

The first set of experimental data was obtained using the same test rig that was in use at BSRIA when collaboration began. Studies investigating the interaction of chilled ceilings with semi-cylindrical wall mounted displacement diffusers had already been carried out in the test room. Although it proved difficult to match the room heat load exactly, 50 W/m^2 rather than 40 W/m^2, the results from these studies would provide the reference for the tests with the textile diffusers, with respect to their ability to limit the temperature rise in the room. This experimental programme was designed to establish the following:

i) whether a textile diffuser could be used as a low level supply device to achieve a displacement effect in a room

ii) whether a significant increase in air supply rate could be achieved without producing unacceptably high velocities in the occupied space

iii) whether the increase in air supply rate produced a satisfactory temperature regime in the occupied space to eliminate the need for supplementary cooling in typical commercial office situations.

5.1 Description of test facility

The test facility was constructed in a laboratory at the Crowthorne site of BSRIA, to conduct physical modelling tests as part of the 'Chilled Ceilings and Displacement Ventilation in the Office Environment' sponsored project. The room was constructed to replicate a typical modern office arrangement.

The test facility was constructed to form a room with internal dimensions of 10 m by 6 m by 2.7 m in height, with glazing panels in the 6 m wide walls. The 500 mm deep insulated floor was constructed on the concrete floor of the laboratory. The walls of the room were constructed from 50 mm by 100 mm timbers on to which 12 mm chipboard panels were screwed to form the inner wall surfaces. The outer skins of the walls were formed using 6mm hardboard sheets. Glass fibre insulation was used to fill the cavity between the inner and outer leaves of the wall. The roof of the room was constructed from 225 mm by 50 mm timbers that spanned the 6 m ceiling width. 12 mm chipboard panels were attached above and below the timbers, and 100 mm glass fibre insulation was laid in the cavity between the panels.

The room had a modular raised floor system over a 600 mm void that was used to distribute the supply air distribution ducting. This system comprised adjustable metal columns on which sheet metal clad floor panels, 600 mm by 600 mm by 40 mm thick, were supported. Standard foam backed office carpeting was laid over the floor tiles.

The room also had a suspended ceiling with a void of 1.2 m above it, used as an extract plenum. This ceiling comprised a mixture of acoustic metal panels, 1.2 m by 0.6 m, and a combination of chilled beams and panels.

The thermal properties of the materials used in the various elements of the facility, and their calculated U-values are shown in the Tables 5.1 and 5.2.

Table 5.1 Thermal properties of test room materials

Material	**Thermal Conductivity ($Wm^{-1} K^{-1}$) (CIBSE Guide A 1986)**
Hardboard	0.130
Chipboard	0.150
Fibreboard	0.060
Carpet (synthetic)	0.060
Glass fibre slab	0.035

Table 5.2 Calculated U-values for test room elements

Element	**Area (m^2)**	**U-value ($Wm^{-2} K^{-1}$)**
Floor	60.00	1.07
Walls	86.40	0.36
Windows	6.84	2.8
Roof	60.00	0.32

5.2 Test facility plant

5.2.1 Chilled ceiling plant

A water-to-water refrigeration system was used to supply chilled water to the cooled ceiling devices, and a 30% solution of glycol antifreeze was used in the primary water to prevent icing during operation. Primary water was pumped to a heat exchanger coupled to the secondary water circuit that supplied the cooled ceiling system. Water in the secondary circuit passed through another small vessel containing a temperature regulated electric immersion heater before supply to the cooled ceiling devices. The electric immersion heater was controlled by a sensor in the water flow, linked to a Eurotherm controller. Figure 5.1 illustrates both the primary and secondary water systems.

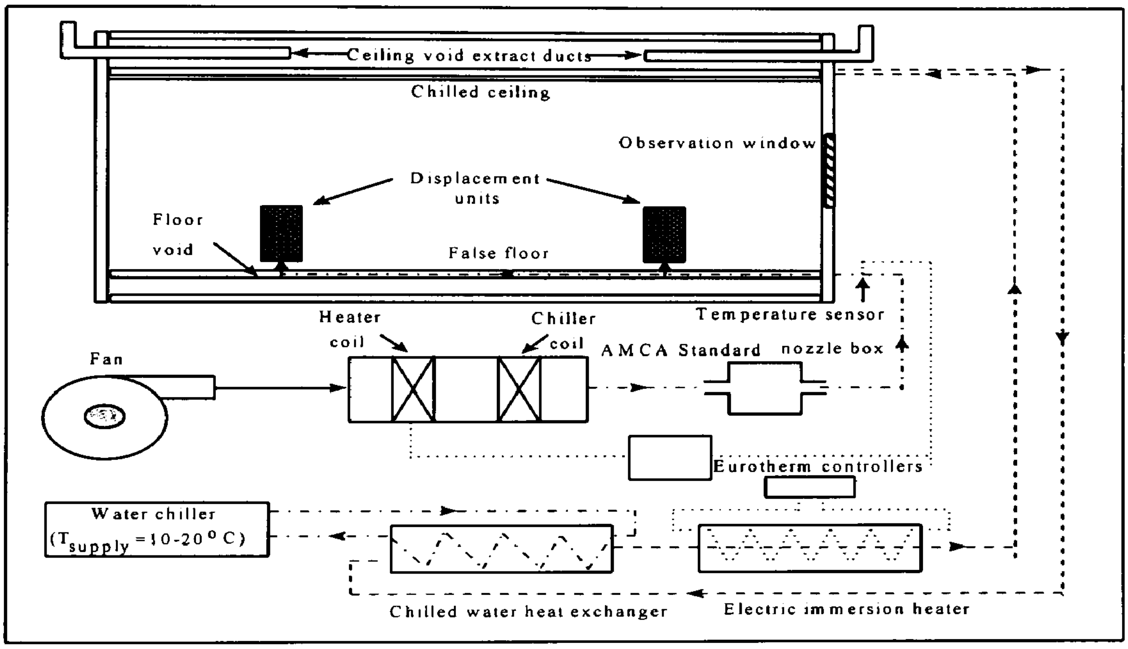


Figure 5.1 Initial test facility

5.2.2 Air supply plant

Air was supplied to the room by four displacement air terminals, (LVB 100), which were provided by Halton Products Limited. The four air terminals were floor mounted, with the supply duct branches located and connected beneath the raised floor, having a 99 mm circular spigot for connection to supply ductwork. The terminals, 500 mm in height, were a composite of a rectangle and a semicircle plate, the rectangular part being

207 mm by 76.5 mm and the semicircular part 103.5 mm in radius. The design of the terminal is fully detailed in Figure 5.2. The terminals were selected using graphical data provided by the manufacturer, which showed air velocity versus distance from the terminal outlet for three specified air volume flow rates. For the LVB 100 terminals selected, the maximum air volume flow rate of 40 l/s produces a face velocity of 0.2 m/s, decaying to 0.1 m/s at a distance of 2 m from the discharge.

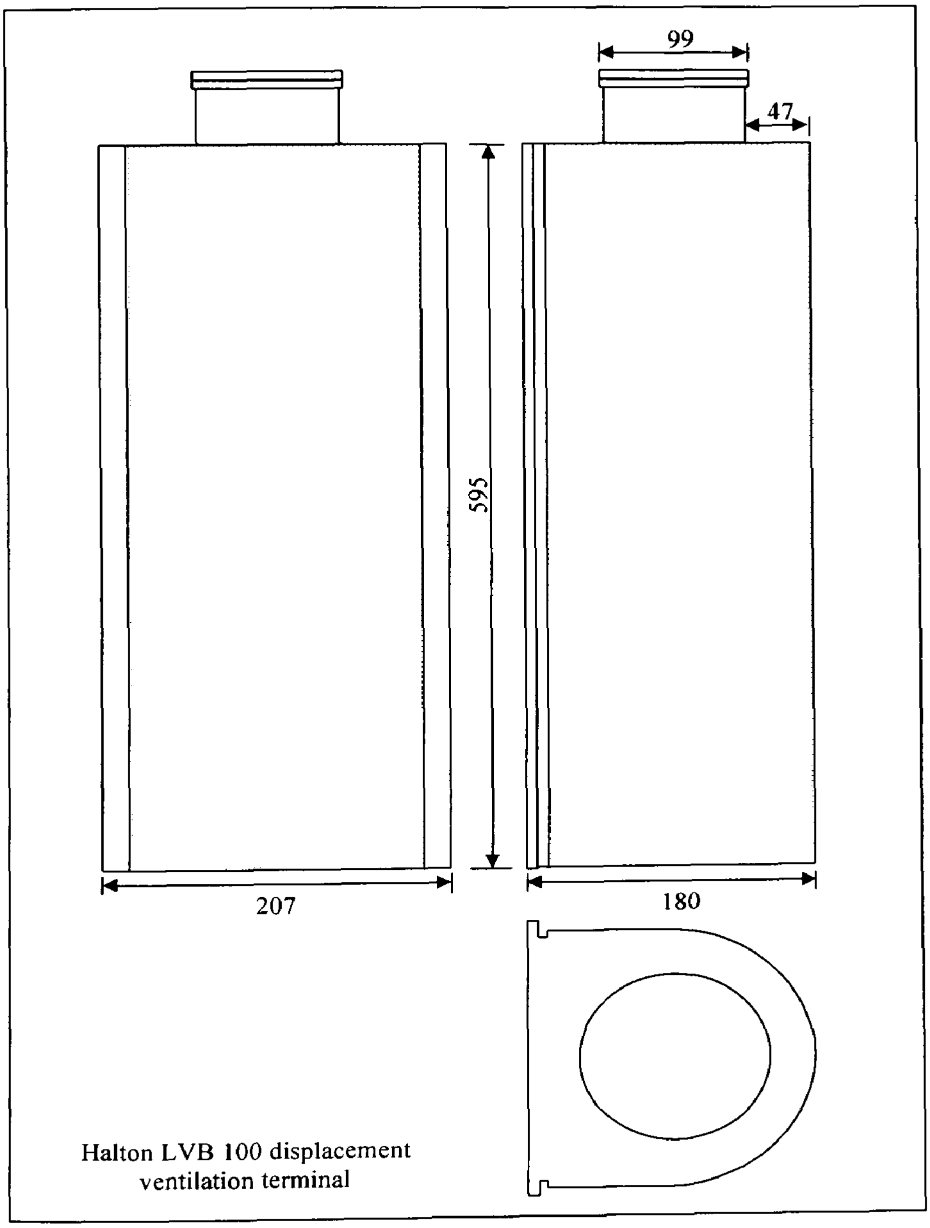


Figure 5.2 Diffuser detail

The main air supply duct, constructed from 25 mm thick, aluminium foil coated poly-isocyanurate boards, was square in section and had internal dimensions of 300 mm by

300 mm. This duct was routed lengthways along the centreline of the void. Four 150 mm diameter spiral wound circular ducts came out of the main duct at right angles, each one leading to a connection with each of the displacement ventilation air supply terminals. These ducts were insulated with a 50 mm glass fibre wrap. Transformation pieces were used to reduce the ducts' diameter for connection to the terminal spigots. Each of the supply branches was fitted with a flow regulating "iris" damper and a ring of static pressure tappings for airflow balancing. The ductwork is insulated to minimise heat gain or loss between the air handling unit and the supply diffusers. Figure 5.3 shows the supply air duct system for the air handling unit to the supply air terminals.

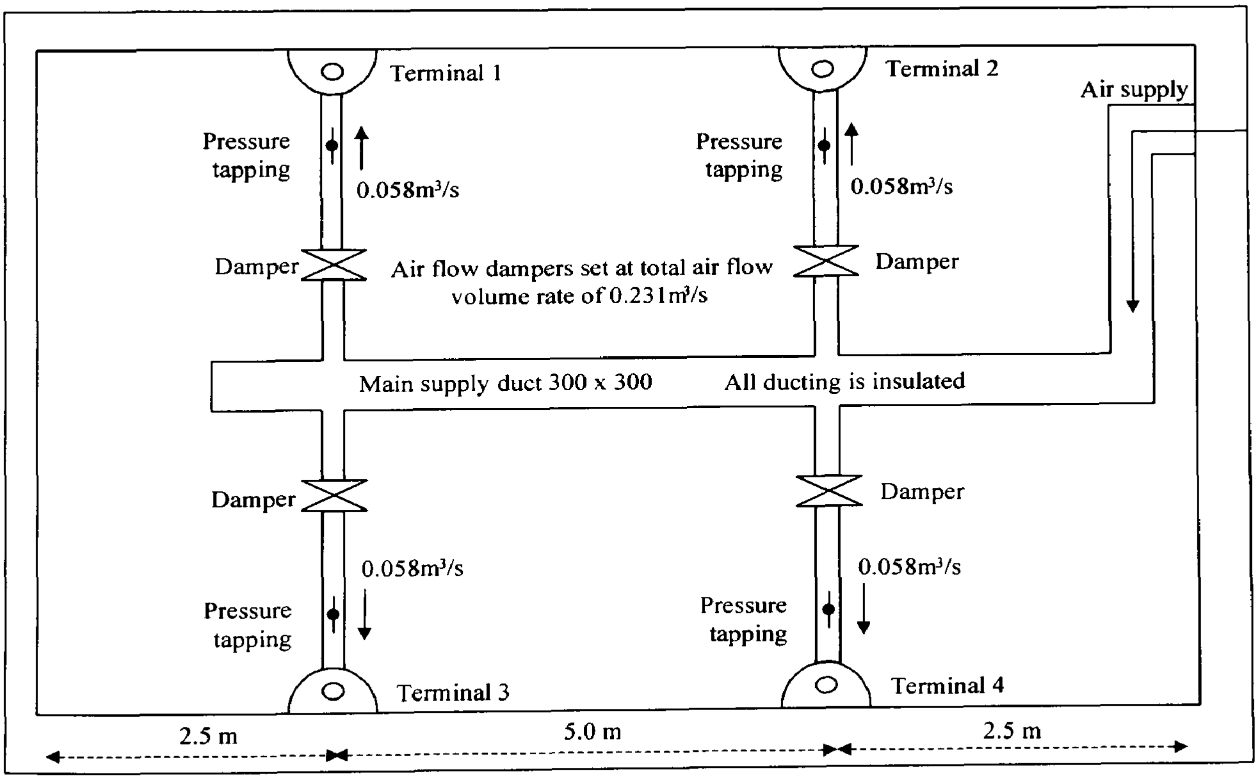


Figure 5.3 Displacement ventilation supply air system

An air handling system giving full temperature control of the supply air was used. The system comprised a centrifugal fan, chiller and expansion coil, an electric heater battery, and a feedback controller for regulating heat emission, and hence air supply temperature from the heater battery. A damper at the fan inlet was used to regulate the air volume flow rate through the system. A nozzle box (AMCA Standard 500-89) was used to measure the air volume flow rate.

Air supplied to the space was extracted through the ceiling void via two 150 mm diameter ducts which had openings situated at approximately 2.5 m from each of the 6 m end walls. The ducts emerged at high level through the walls of the facility and were routed to the roof or upper surface where they each connected to the inlet of a centrifugal fan. A damper on the outlet of each fan was used to regulate the rate of air extraction in equal amounts such that the net pressure differential between the facility and the laboratory was zero when the access door was closed. This ensured that the only air entering the room was treated air via the supply diffusers. Figure 5.1 shows both the supply and extract air handling systems.

5.2.3 Chilled ceiling devices

Chilled beams – the beams were manufactured from 22 mm diameter copper tubes pressed through fins of thin aluminium foil plates, measuring 110 mm by 110 mm by 0.38 mm in thickness, to provide an interference fit. The aluminium fins were spaced 6 mm apart. Pairs of tubes were supported on brackets such that they were side by side with the tube centres 120 mm apart. Sheet metal returned edges were fitted to the outer sides of the fins, to restrict the air flow. This assembly was in turn housed in a rectangular U-shaped open duct measuring 450 mm in width by 280 mm in depth with baffles to separate the air inlets and outlets. The duct was designed to fit inside a ceiling void with its underside open to the room, but without air being able to pass through it from the ceiling void to the room. The construction of the chilled beam is shown in Figure 5.4.

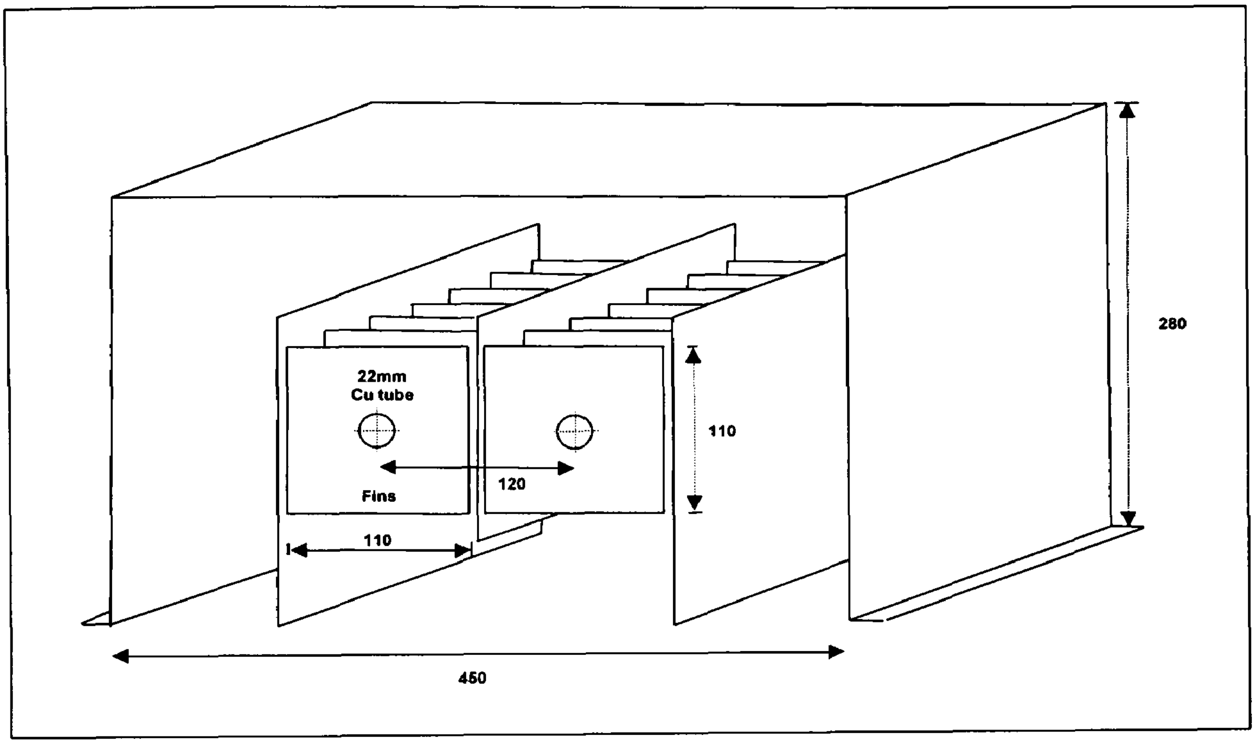


Figure 5.4 Chilled beam construction

Chilled panels – the panels were fabricated from eight individually formed aluminium sections that were fastened together to provide an architectural finish to their underside, and an array of 12 mm diameter clamped copper tubes on their upper surface. The panels measured 4.8 m by 1.15 m. The construction of the chilled panel is shown in Figure 5.5.

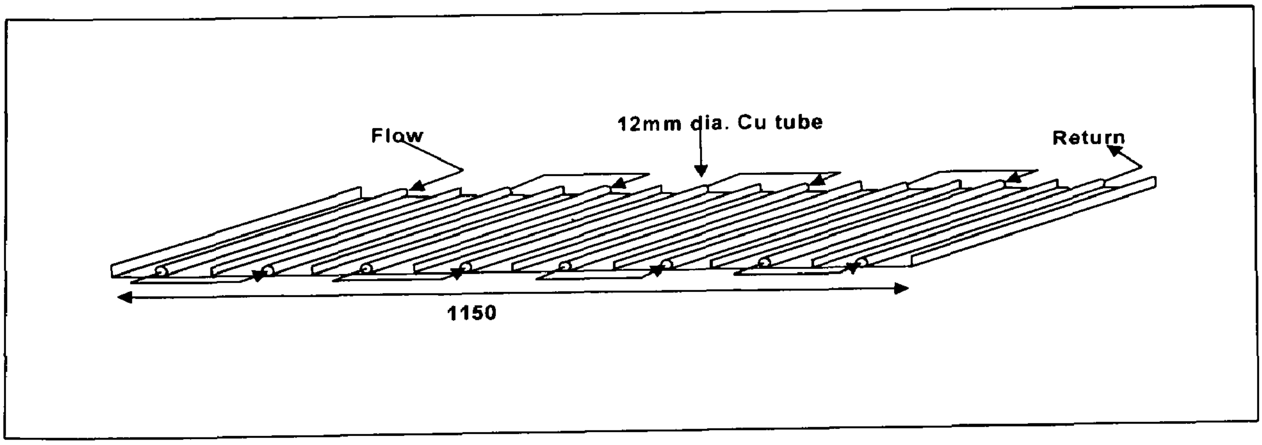


Figure 5.5 Chilled panel construction

5.3 Simulation of thermal gains

Thermal gains in the test facility were categorised as three components:

- lighting gains - high level fluorescent lamps in uplighter fittings
- occupants in a sedentary posture
- office equipment - PCs, printers and a photocopier machine

Where possible, actual office equipment was used and black rectangular boxes, which had a surface area approximately equivalent to an adult person, simulated occupants. Each box, measuring 0.45 m by 0.3 m by 0.75 m in height, was fitted with a 100 W tungsten filament lamp located near the base of the unit. As the occupants were considered to be sedentary, the boxes were positioned in an upright position on chairs adjacent to desks. The design of these occupant simulators was cross-referenced with values stated in the CIBSE Guide A 1986 and the ASHRAE Fundamentals Handbook 1993. Lighting was provided by 12 fluorescent uplight fittings, each with a single high efficiency 28 mm diameter lamp rated at 58 W, which were 1.4 m in length.

The room was arranged for a total of eight occupants, each with a PC. The rated output of each PC was different for each model, while the actual heat output depended on the function being performed by the processor and the display on the monitor. However, electrical loads were constant during testing, and averaged approximately 90 W per PC. A redundant photocopier was used in the facility, which although functional, was not switched on as its output could not be controlled and varied as required. Heater mats simulated the heat load of the photocopier. These were attached to the photocopier to allow thermal outputs to be controlled and varied from 0 to 1800 W as required. Two printers were installed each making a thermal contribution of approximately 50 W. Thermal loads were varied by installing the black boxes on chairs, and operating selected PCs and printers, 1 to 4 of the heater mats on the photocopier, and half or all of the fluorescent lights as necessary. Figure 5.6 illustrates the distribution of occupants and PCs within the test room.

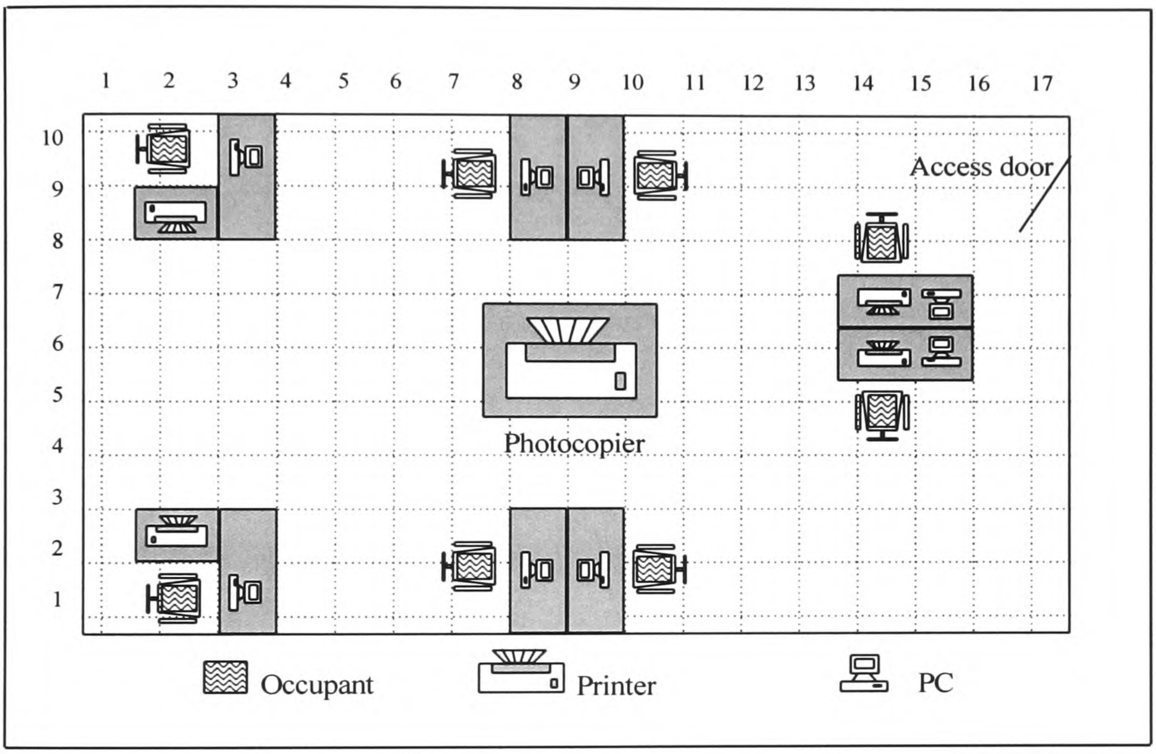


Figure 5.6 Floor plan of original test room showing 600mm grid points

5.4 Control room instrumentation

5.4.1 Temperature

Forty T-type thermocouple wires were used to monitor temperatures for measurement and control purposes in and around the facility. The thermocouples were connected to a multi-channel microprocessor based data acquisition system. This comprised of a Solatron Schlumberger Orion 3530A Data Logging System, containing an electronic circuit equivalent to the cold junction necessary for a bridge circuit. Millivolt signals generated by the thermocouples were converted in the processor, into units of temperature (^{o}C). Instead of using the data storage facility of the logger, the data was transmitted directly to a PC, to enable on-screen monitoring and data analysis using a spreadsheet package, (Microsoft Office Excel). The thermocouples distributed throughout the test facility for the measurement of air, surface, and water temperatures are identified in Table 5.3

Prior to the installation of the thermocouples, a random selection was checked for calibration accuracy. This was done by installing the sensors of the thermocouples within a calibration chamber at the BSRIA instrument test facility in Bracknell, which can be set to provide a wide range of constant temperatures. The chamber was operated at various fixed temperatures in the range 0 ^{o}C to 40 ^{o}C, and thermocouple readings were compared with readings from a NAMAS accredited precision resistance thermometer. From the sample of thermocouples checked, it was recorded that all temperature readings were within $\pm$ 0.15 ^{o}C of the accredited thermometer.

5.4.2 Air flow rates

Supply air volume flow rates were measured using a 100 mm diameter AMCA Standard (AMCA Standard 500-89) nozzle box. Air volume flow rates were determined by measuring the difference in static pressure occurring across the profiled nozzle and applying a relationship for air volume flow rates versus pressure differentials for the device. Air pressures were measured using a "Time" electronics micro-manometer. Calibration checks of the micro-manometer accuracy have shown the device to be within ± 0.1 Pa of the laboratory standard calibration unit.

Extract air volume flow rates were measured separately for the two extract ducts. This was done by measuring the air velocity pressure profiles in two perpendicular axes through a cross section of one of the ducts for a range of air flow rates using a Pitot static tube. A relationship was subsequently established between the air volume flow rate and the centre line velocity pressure, which was then used as an indicator of the air flow rates through the two extract ducts.

5.4.3 Water flow rates

An in-line turbine water flow meter was used to measure the total water flow rate in the secondary water system, serving the cooled ceiling systems.

5.4.4 Electrical and thermal loads

The electrical power consumption of the black boxes (for occupants) and the office equipment was measured using a kilowatt hour meter manufactured by Emetco Ltd of Folkestone. A second meter recorded the electricity consumed by the lighting. The load was measured by recording the time, t seconds, taken for the meter's rotating disc to complete a full number of revolutions, n, and by calculating the power consumption, P, from the expression:

$$P = n/60t \qquad \text{kW}$$

5.4.5 Environmental instruments used

Air speed and air temperature values in the space were measured using two arrays of six Dantec 54R10 probes incorporating spherical omni-directional hot-film anemometers and thermistors. The probes were mounted on mobile stands, which could be positioned in the space as required. Each probe combined the air speed and air temperature measuring transducers in close proximity, effectively enabling measurement of both variables at a point location. Air speeds could be measured in the range 0.05 m/s to 1.0 m/s. These transducers provide a high degree of sensitivity, being able to resolve temperatures to ± 0.1 ^{o}C and air speeds to ± 0.01 m/s. When calibration corrections have been applied, air temperature errors are less than ± 0.25 ^{o}C and errors for air speed are less than ± 0.03 m/s. It was important that transducers with this degree of velocity sensitivity were used when human comfort criteria include draught sensitivity in the range 0.15 – 0.25 m/s.

The probes were connected to a Dantec 54N10 multi-channel flow analyser to convert electrical signals into speed and temperature values, and to store and process the results. The processed sets of data include mean speed and temperature values and this is exported via a communications port to a PC for recording and analysis.

Mean radiant temperatures were measured using T-type thermocouple wire with each of the two sensing junctions positioned at the centre of a 100 mm diameter blackened sphere. The thermocouple signals were treated by the same processor that was used for the control temperature measurements in and around the facility.

Table 5.3 Thermocouple locations

Channel No.	Location	Channel No.	Location
1	Air terminal riser 1	21	Panel surface 1
2	Air terminal riser 2	22	Panel surface 2
3	Air terminal riser 3	23	Supply radiant panels
4	Air terminal riser 4	24	Return Radiant panels
5	Extract air terminal 1	25	Supply chilled beams
6	Extract air terminal 2	26	Return chilled beams
7	Spare	27	Globe 1
8	Under beam 1	28	Globe 2
9	Supply duct entry	29	Ceiling
10	Internal surface wall 1	30	Column 1 – 50mm
11	Internal surface wall 2	31	Column 1 – 917mm
12	Internal surface wall 3	32	Column 1 – 1783mm
13	Internal surface wall 4	33	Column 1 – 2650mm
14	External surface wall 1	34	Column 2 – 50mm
15	External surface wall 2	35	Column 2 – 917mm
16	External surface wall 3	36	Column 2 – 1783mm
17	External surface wall 4	37	Column 2 – 2650mm
18	Under floor surface	38	Above beam 1
19	Floor surface	39	Above beam 2
20	Facility roof surface	40	Under beam 2

5.5 Test procedure

5.5.1 Commissioning the facility

Before the start of the test programme, the various plant systems were commissioned to ensure correct operation. This involved balancing the air supply to each of the displacement terminals and balancing the extract air from the exhaust ducts in the ceiling voids. Additionally, the temperature of the supply air was set so that design values were achieved at the points of discharge.

The commissioning started with balancing the air supply to the displacement terminals. The supply fan was set to provide a quarter of the design flow rate, with three of the four supply air branches isolated. The static pressure downstream of the damper in the active branch was then measured and noted for comparison with the static pressures measured in the other three branches as each was operated in turn. The dampers in each branch were adjusted to ensure that all four static pressures were equal when they were operated individually and subsequently when they were operated in unison with the total flow rate required.

The controller regulating the supply air temperature was also adjusted to ensure a nominal value of 19 ^{o}C at the terminal risers.

Air flow through the extract fan was adjusted by restricting the fan outlet until measurements of air flow using the pitot-static tube indicated the appropriate value, approximately 1% higher than the supply rate, to allow for thermal expansion.

Commissioning valves in the flows to the chilled ceiling panels were set so that equal water flow rate was achieved through each device. The total water flow rate in the secondary circuit was measured using a turbine meter and the flow adjusted accordingly. The refrigeration equipment was set to provide the necessary cooling source in the primary water circuit. The water temperature was set to ensure a nominal 14 ^{o}C at entry to the panels.

5.5.2 Condition set-up and procedure

With the aim of achieving steady state conditions within the test room the following procedure was carried out in the evening of the day before the data logging exercise.

i) Switch on fluorescent lighting.

ii) Distribute and switch on the black boxes (occupants).

iii) Turn on the PCs, printers and set photocopier heater mats to the required load.

iv) Turn on the supply air fan and set the volume flow rate to the desired value.

v) Set the supply air temperature controller to provide an air temperature of 19 ^{o}C at the point of discharge.

vi) Set the water flow rate for the cooled ceiling devices at a value consistent with the nominal supply/return temperature differential for the given cooling effect.

Once the above sequence has been completed, the electrical loads can be confirmed using the Emetco kWh meters. Once the combined load was established to be within $\pm$ 60 W (or 1 W/m^2) of the test specification, appropriate internal gains were deemed to be achieved.

With the facility set up and in operation, a number of key temperatures, i.e. supply air, internal surfaces and sampling columns were monitored, to establish that steady state conditions were being achieved. Steady state was considered achieved if changes in both the mean of the internal surface temperatures and the mean of the column temperatures were found to be less than 0.3 ^{o}C in one hour. Sampling was taken at six minute intervals.

Supply air temperatures were found to stabilise within 10 to 15 minutes. This was anticipated, as the supply ducts had a low thermal mass. In contrast, the test facility as a whole had a large thermal mass and was found to take two to four hours to stabilise. Problems were experienced with this long stabilisation period because over the four hours the conditions in the laboratory building could also change. This meant that steady state conditions were jeopardised. This problem was one addressed in the re-design of the test room described in Chapter 6.

To evaluate the thermal regime and air flow within the space, air temperatures and air speeds were sampled on two columns in the test room at heights of 0.225 m, 0.675 m, 1.125 m, 1.575 m, 2.025 m and 2.475 m. The instrument columns were located at points spaced at 600 mm on a regular square grid. The columns were positioned at two points in the room and left for a period of approximately 4 minutes for conditions to stabilise following disturbance caused by moving the columns. The instruments then sampled for a period of 180 seconds with the results recorded. Both columns were then moved to new positions and the process repeated until every accessible point on the grid had been monitored. The total test period was approximately ten hours. Fig. 5.6 shows the grid in the test facility on which air temperatures and air speeds were sampled.

5.6 Test programme

The reference data for comparison were taken from the test programme of the BSRIA 'Chilled Ceiling and Displacement Ventilation' project. The data set chosen was for a cooling load of 40 W/m^2 treated by displacement ventilation only, delivered by four Halton LBV 100 terminals with a combined air volume flow rate of 157.5 l/s, equating to 3.5 air changes per hour.

When the test facility became available for the textile diffuser tests, the room load was stable at 50 W/m^2. Although higher than for the reference test data, the opportunity to use the test room was limited, and it was decided to proceed with this load as it would provide evidence in absolute terms, and for comparison with reference data, account could be made for the difference in cooling load. As the reference data showed that 3.5 air changes per hour was clearly failing to control the temperature to acceptable levels, the air change rate was doubled to 315 l/s or 7 air changes per hour. Observations made on the data, as it was collected, indicated that air velocities were very low, and that there was scope for increasing the air supply flow rate. With a room loading of 50 W/m^2, this increase still allowed for appropriate comparison with the reference data. The maximum air flow rate available from the air handling unit was 418.5 l/s or 9.3 air changes per hour. This flow rate was used to identify whether the threshold was being reached for the textile diffusers in terms of creating unacceptable velocities.

5.7 Feasibility study results and analysis

The results for room air temperatures and velocities are presented graphically below, in Figures 5.7 – 5.10. A full record of the data collected is located in Appendix I.

5.7.1 Temperature

To obtain an overview of the system performance, average temperature and velocity values were calculated for each recording height in the room.

The average temperature profiles indicate that at the higher air flow rates available from the textile diffusers, the temperature rise in the room is effectively controlled, when compared with the performance of the Halton LBV 100 Standard 'bin type diffusers. The question of what is an acceptable temperature at the top end of the comfort range is not straightforward. Relative humidity has a significant bearing at higher temperatures, as does duration of exposure. Many designers work on a maximum of 26 °C (ISO 7730 1992, CIBSE Guide A 1986), with 23 °C being desirable.

With a cooling load of 40 W/m^2 and the Halton diffusers in use, the average temperature at the top of the room, (2.475 m), is 32.5 °C, Figure 5.7. This would be unacceptably high if it were in the occupied zone, rather than above head height. However, at standing head height, (1.575 m), the average temperature is 32.2 °C and at sitting head height, (1.125 m), it is 31.5 °C. This clearly demonstrates that at cooling loads in excess of 20 W/m^2, the airflow limitations of the bin-type diffuser results in serious overheating. When the airflow rate is doubled using the textile diffuser, as expected the temperature control is better, 26.8 °C, 25.3 °C, and 24.2 °C respectively, Figure 5.7. This was with an increased cooling load of 50 W/m^2, but is nevertheless just within acceptable temperature limits. With the airflow rate increased further (9.3 air changes per hour) to compensate for the higher cooling load, and to test the velocity limitations of the diffuser, the respective average temperatures (see Figure 5.8) were 25.5 °C, 23.5 °C and 23.1 °C.

The other temperature related comfort criterion is 'vertical temperature gradient', which should be limited to 3 K from ankle to head, or 3 K/m sitting (ISO 7730 1992, CIBSE Guide A 1986). For the set of results at 9.3 air changes per hour, the average temperature at the lowest reading position (see Figure 5.8) was 21.1 °C, giving a vertical gradient of 2 K ankle to head, (2.2 K/m), sitting, and 2.4K ankle to head, (1.8

K/m), standing. Therefore, for a predominantly seated occupancy as in offices, these results suggest that loads higher than 20 W/m^2 can be controlled by displacement ventilation alone without resorting to static cooling devices. This is a particularly significant finding.

However, the use of the averages to determine a profile for the room could of course be concealing unacceptably high values at the top end of the range of temperatures recorded across the room.

A study of the detailed data in Appendix I reveals the following:

	Number of Readings > 26 ^{o}C	Maximum temperature at seated height (^{o}C)	Maximum temperature at standing height (^{o}C)
Textile diffuser at 7.0 air changes per hour	0	24.8	26
Textile diffuser at 9.3 air changes per hour	0	24.9	25

It is clear from this that there are no localised anomalies to the acceptable regime. In order to make a fair comparison between the textile and the conventional diffuser, the same measurement grid was used. In practice, this penalised the performance of the textile diffuser. The textile diffuser was installed along the entire length of the two long walls of the test room and consequently for all of the grid points on the y = 1 and y = 10 axes, the measuring probes were actually in contact with the textile diffuser. As the occupants would not be in contact with the diffuser, these readings could be excluded from the calculations. This would result in a foot level temperature of 21.3 °C instead of 21.1 °C, giving an even more acceptable temperature gradient.

5.7.2 Velocity

As discussed in 5.7.1, the use of textile diffusers at high air flow rates produces an acceptable thermal environment. The concern is that this might be at the expense of draught risk. The velocity profiles for 7 and 9.3 air changes per hour, Figures 5.9 and 5.10 show that the textile diffusers are able to discharge significantly higher air flow rates into the room than the standard 'bin type' Halton diffusers, with no significant increase in room air velocities. The highest average velocity indicated is 0.07 m/s, which is well within accepted comfort criteria. (CIBSE Guide A 1986). There should be no draught discomfort when velocities are below 0.15 m/s. Again, the use of the averages to obtain a profile for the room raises the possibility that this could be concealing unacceptably high values at the top end of the range of velocities recorded across the room.

A study of the detailed data in Appendix I reveals the following:

	Number of Readings > 0.15 m/s	Maximum reading (m/s)
Textile diffuser at 7.0 air changes per hour	1	0.168
Textile diffuser at 9.3 air changes per hour	8	0.186

The initial suspicion was that, as with the temperature readings, the worst case readings would be where the sensors were pressed into the textile diffusers. However a study of the results indicated that the readings above 0.15 m/s were almost exclusively close to the heater mats on the photocopier. This was a very large point source heat load (500 W) creating considerably stronger convection currents than an occupant, typically (100 W), and hence relatively high air velocities. This indicates that it is not appropriate to use large point sources as part of the heat load when monitoring thermal comfort parameters. It is clear that momentum forces from the supply diffusers did not produce these higher velocities.

It may be concluded that the velocity regime when using textile diffusers to supply up to 9.3 air changes per hour is as acceptable as the velocity regime when using standard displacement diffusers to supply 3.5 air changes per hour. Furthermore it is evident from these results that when the textile diffuser is used, there is no draught discomfort zone as there is with the Halton bin type diffuser. This limitation with the use of bin type diffusers is identified and discussed in 1.2.2.3.

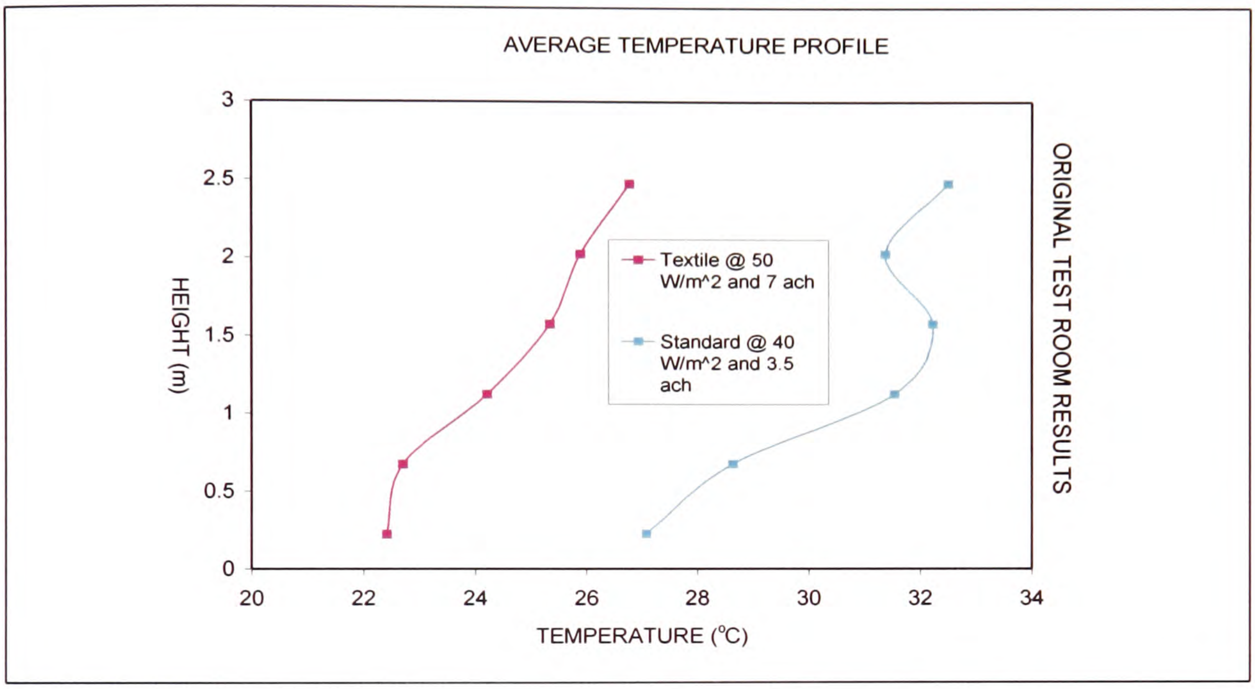


Figure 5.7 Original test room average temperature profile comparisons (7 ac/h)

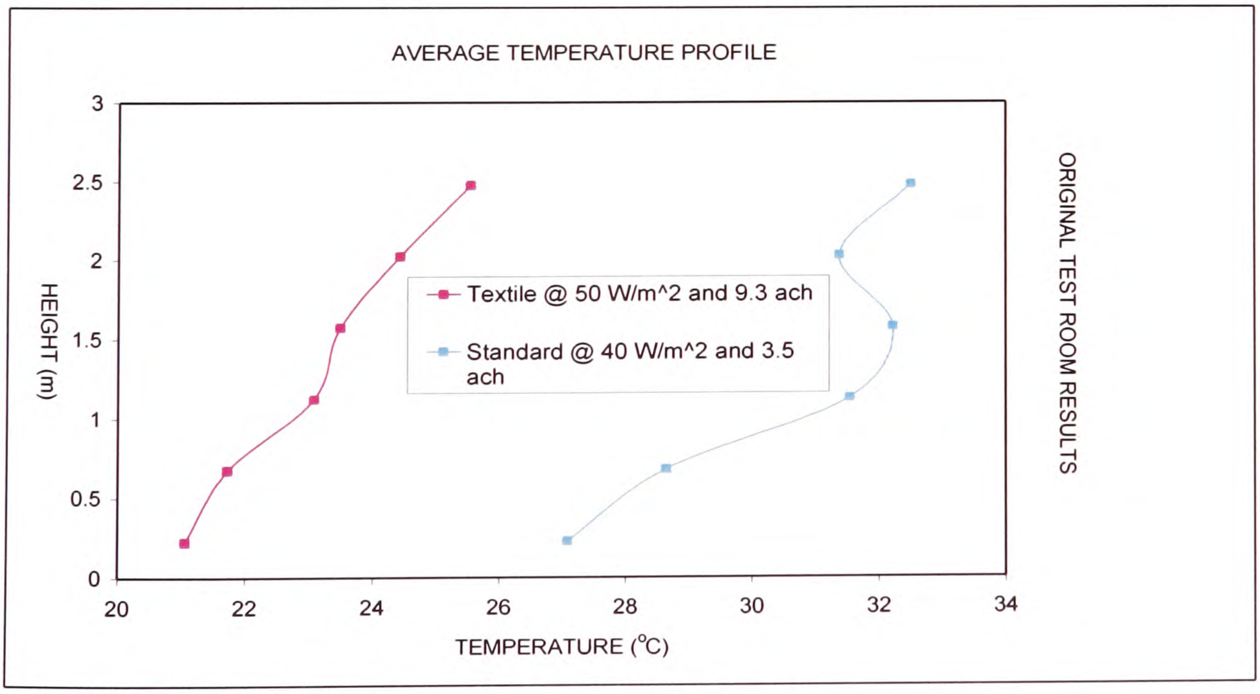


Figure 5.8 Original test room temperature profile comparisons (9.3 ac/h)

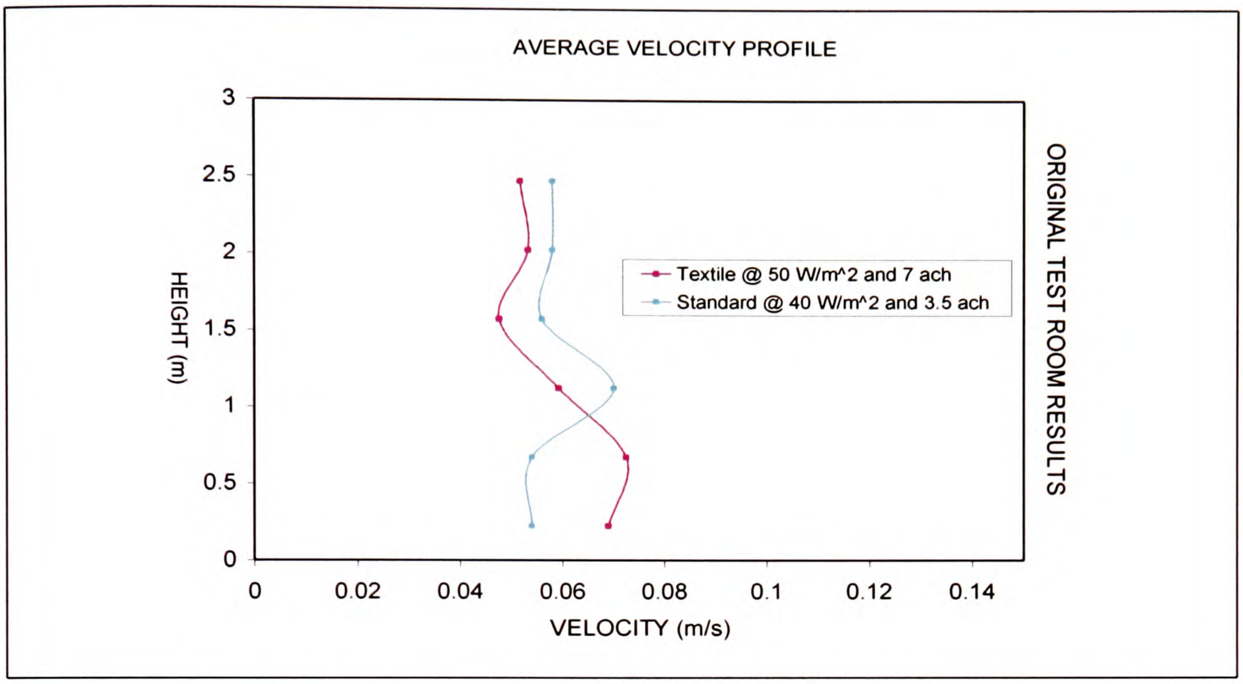


Figure 5.9 Original test room average velocity profile comparisons (7 ac/h)

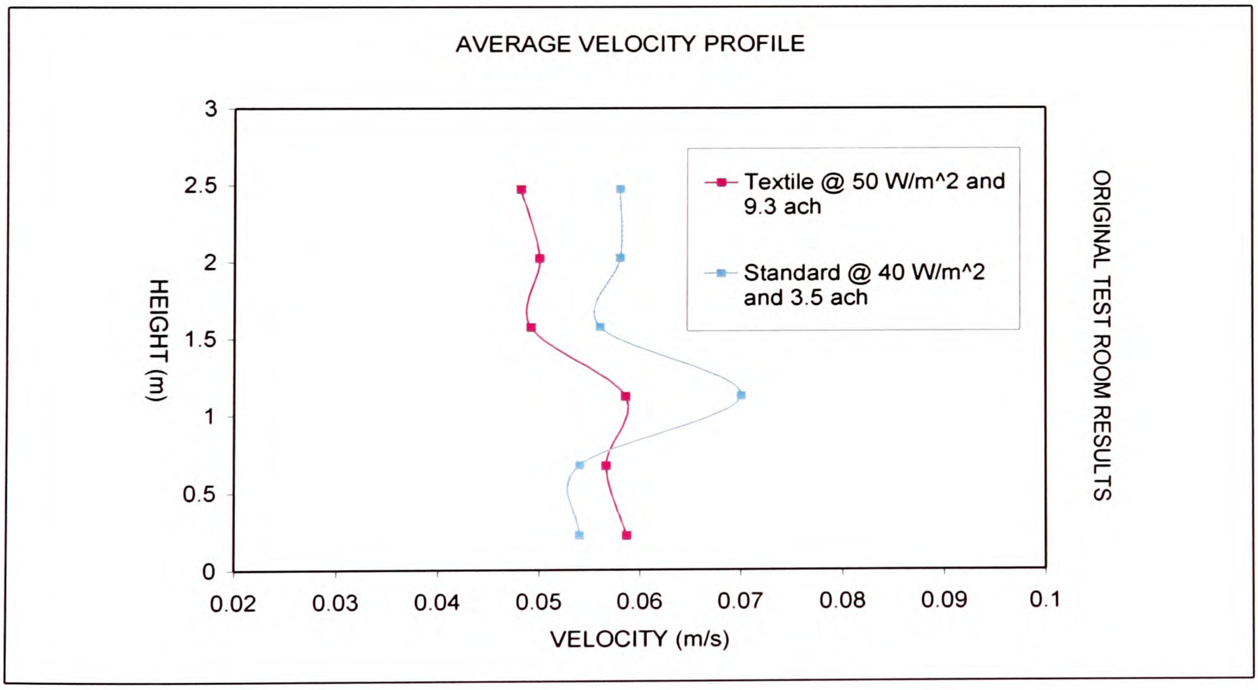


Figure 5.10 Original test room average velocity profile comparisons (9.3 ac/h)

Chapter 6

Experimental Programme in Modified Test Facility

6.0 EXPERIMENTAL PROGRAMME IN MODIFIED TEST FACILITY

6.1 Re-design of test room

Following the completion of the feasibility study, further tests were conducted with the textile diffusers to confirm that the results were repeatable. Before undertaking further tests, the design of the test room was reviewed. The following problems were identified:

i) The size of the test room and therefore the number of test points to be monitored resulted in a test period of the order of ten hours. This placed restrictions on the number of different situations that could be investigated, as the availability of the test room was limited.

ii) The size of the test room and the length of the test period created further problems. The laboratory housing the test room was not thermally stable over such a long period, and the number of thermocouple points in relation to the size of the room, reduced confidence in the accuracy of the calculation of the heat flux from the room. Confirmation that steady state conditions had been achieved, was also difficult, and time consuming.

iii) The use of heater mats as part of the cooling load created a point load resulting in localised high velocities, which gave a misleading impression of the displacement airflow regime, as discussed in 5.7.2. The internal fans on the PCs used as part of the cooling load also disrupted the displacement airflow characteristics. This can be seen as an increase in velocity at a height of 1 m in the performance curves for the original test room shown in Section 5, Figures 5.9 and 5.10. Although in use in real buildings, the systems would be subject to such disturbances, it was felt that they should be eliminated for experimental work to establish pure performance characteristics. The evaluation of the performance of the system in operational buildings can then be made against this.

The conclusion was that a smaller test room should be built within the original test room. This would reduce the number of test points and hence the duration of the test period and would also provide a more stable 'external zone' allowing closer control and measurement of the boundary conditions. The test room so created was designed as a two person office with dimensions 4.5 m by 4.5 m by 3.4 m. Three walls were constructed from insulated slabs composed of polyiso-cyanurate foam faced with plywood, and the double glazed wall of the outer chamber formed the fourth wall. The roof of the test room was constructed from sheets of plasterboard suspended from steel hangers, and backed with glass fibre mats. The floor of the outer chamber also formed the floor of the new test room. All joints between the structural elements were sealed using adhesive tape to minimise air leakage. The test room surface areas and U-values for each element are shown in Table 6.1 below. The arrangement of the new test room within the existing facility is shown in plan and elevation in Figures 6.1 and 6.2.

Table 6.1 Test room surface areas and U-values.

Element	Area (m^2)	U-value (W/m^2K)
Floor	20.25	1.070
External walls	9.11	0.360
Internal walls	41.95	0.717
Ceiling	20.25	1.210
Windows	4.84	4.000

6.2 Modified test room plant

The chilled water system was retained for the new arrangement. The air handling plant was more sophisticated than for the original room, having been installed for a subsequent condensation control test programme. The unit was controlled by a Landis & Staefa BMS system, and air was continually re-circulated through the unit. The same Halton LVB 100 displacement diffusers were used, but reduced in number from four to two.

The ceiling arrangement is shown in Figure 6.3. The perforated ceiling tiles were constructed from 0.7mm zintec steel. The perforation was such that the free area of each tile was 64% of the total exposed area, (51.1% when trim strips were included). Each trim contained two light fittings containing two 35W fluorescent lamps. The ceiling incorporated 3 Halton CPF 300 chilled beams, and three banks of seven Cosy ESA type chilled panels. The chilled panels were constructed from steel plate with a perforated finish with back-insulated copper piping attached to the upper surface. These panels were interchangeable with the perforated ceiling tiles.

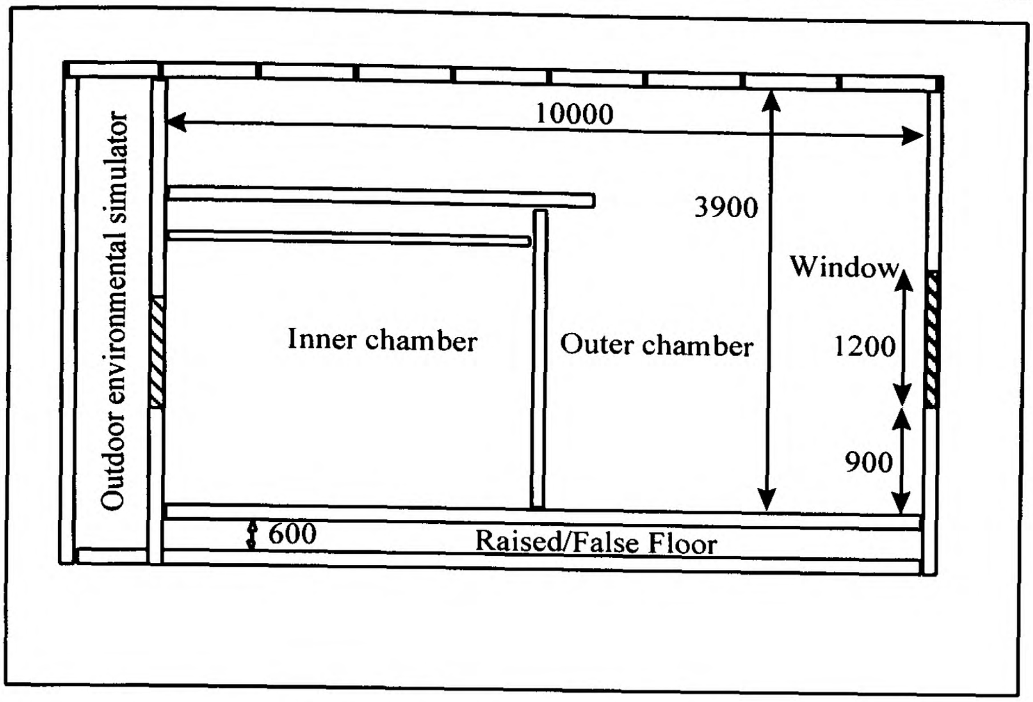


Figure 6.1 Cross section through modified test room

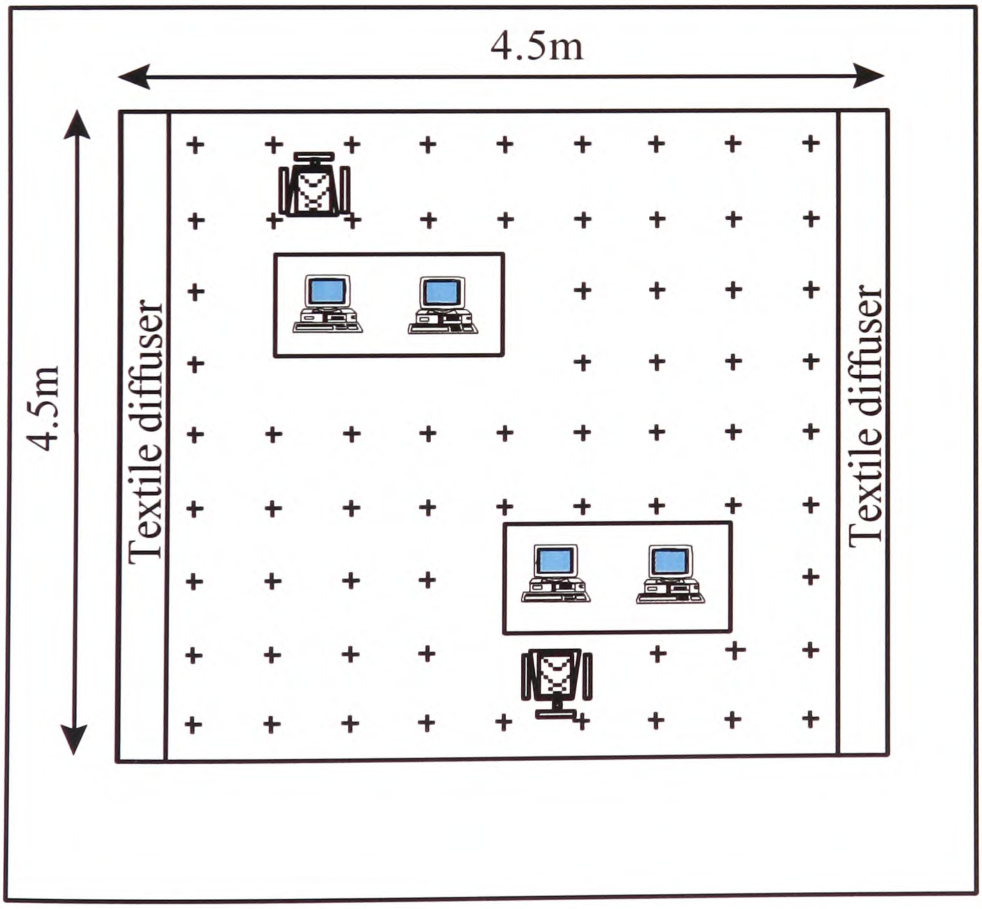


Figure 6.2 Plan view of modified test room

The heat gains were designed to represent occupants and equipment and comprised the following items:

i) Two "black body" occupants, re-used from the original test facility.

ii) Four simulated PCs instead of the real PCs used in the original test facility. These were constructed from 1mm plate steel, and were painted light grey to emulate the radiative properties of a typical computer casing. Each computer contained a 150 W tungsten lamp. This is representative of a typical PC load (Parsloe C 1992).

iii) Four twin tubed fluorescent lights manufactured by Phillips, each lamp rated at 35 W. The total heat gain including ancillary equipment was measured at 282 W.

The lowest practicable incident load achievable with the above equipment was 347 W or 17.14 W/m^2, achieved by using only two of the banks of lights and having two 'occupants' at their desks but without their computers on. The highest load was 1073 W or 53W /m^2 with all equipment on. These values are representative of the low to mid-range internal gains that might be expected in a typical office (Parsloe C 1992). If it can be demonstrated that displacement ventilation can deal with these loads without the assistance of static cooling devices, the decision to use static cooling devices to deal with any additional load from solar gain can be balanced against designing out solar gains. The layout of the furniture, lighting and other heat gains is shown in Figures 6.2 and 6.3.

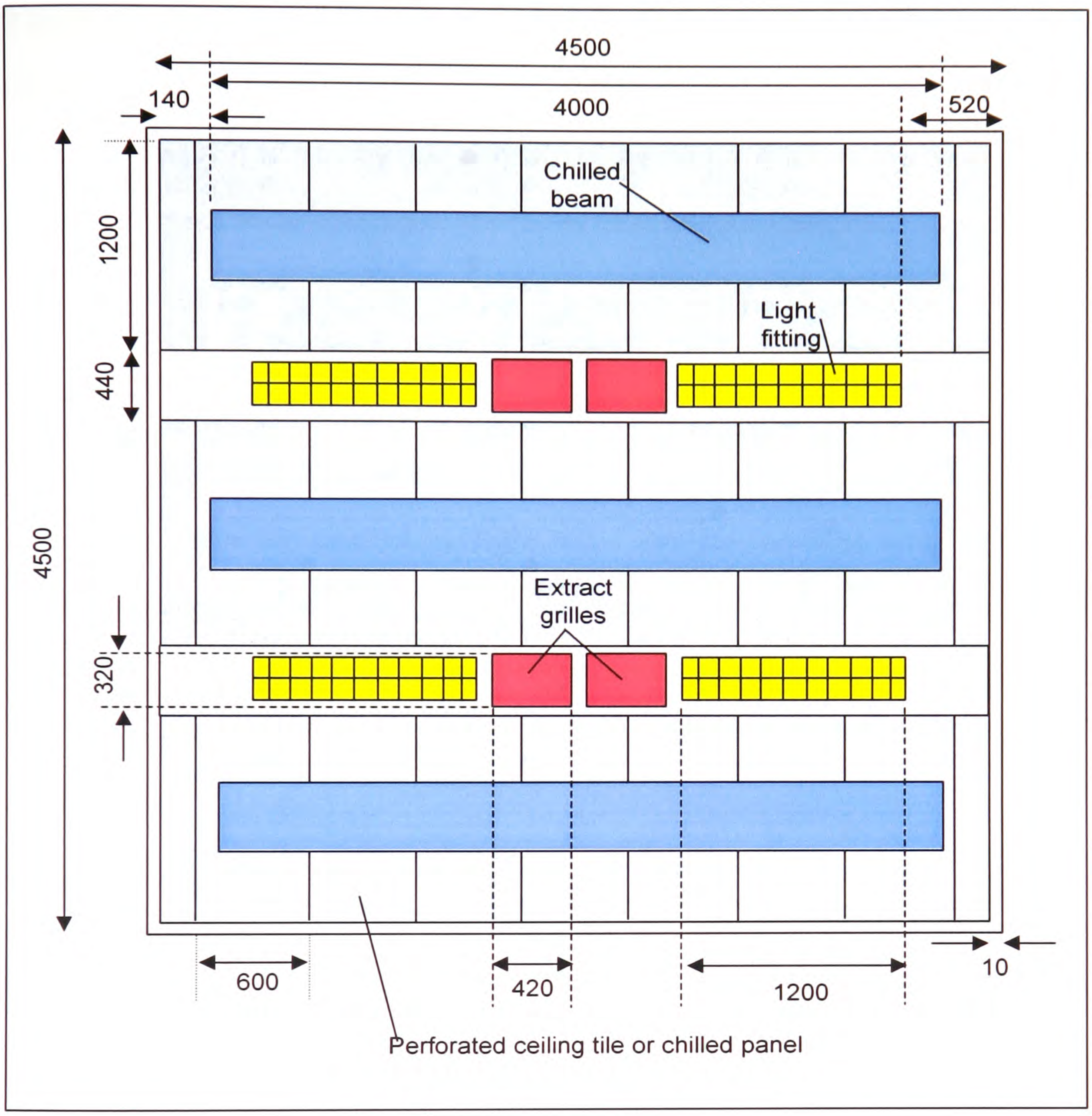


Figure 6.3 Modified test room ceiling arrangement

6.3 Instrumentation and data acquisition

Air speed and air temperature measurements in the space were once again carried out using two arrays of six Dantec 54R10 probes incorporating spherical omni-directional hot-film anemometers and thermistors. The probes were mounted on mobile stands, which could be positioned in the space as required.

The probes were connected to a Dantec 54N10 multi-channel flow analyser to convert electrical signals into speed and temperature values, and to store and process the results. The processed sets of data include mean speed and temperature values and these are exported via a communications port to a PC for recording and analysis.

To analyse and record the ambient temperature, 70 T - type thermocouples were distributed around the internal and external surfaces and the surrounding voids, as well as two columns of eight thermocouples in the environmental chamber. The locations of the thermocouples are detailed in Table 6.2. The dry resultant temperature was measured at heights of 0.6 m and 1.1 m on each stand by placing a thermocouple within a matt black spherical globe, which, in combination with the air temperature and air speeds, allows the radiant temperature to be calculated. (CIBSE Guide A1 1986).

In the revised rig the temperatures, of both the flow and the return water to the chilled panels, were measured using six 1/10th DIN Pt100 sensors. The data were recorded on a Hewlett Packard 75000 Series B data logger. This was linked to a PC where the data were transferred to a Microsoft Excel spreadsheet using dynamic data exchange. Consequently the data could be both tabulated and graphically presented thus enabling real-time heat balances to be carried out and also allowing real-time monitoring of the system. This also gave an accurate indication of when steady state conditions were being achieved.

The water flow rates through the chilled ceiling components were calculated by measuring the pressure drop across Hattersley 1000L low flow orifice plate commissioning sets, using a Perflow U-tube manometer containing a fluoro-carbon

Table 6.2 Thermocouple and PRT locations

No	Location	No	Location
0	Air supply 1 – LHS	35	Wall 4 outside surface at 2m (glass)
1	Air supply 2 – RHS	36	Wall 4 outside surface at 2.5m
2	Air supply 3 – Control Point	37	Wall 4 external ambient at 1m
3	Extract 1 – Near window	38	Wall 4 external ambient at 2m
4	Extract 2 – Near door	39	Roof ambient 1
5	Globe 1 – Pole 1	40	Under floor 1 – LHS near window
6	Globe 2 – Pole 1	41	Under floor 2 – RHS near door
7	Globe 1 – Pole 2	42	Under floor 3 – LHS near door
8	Globe 2 – Pole 2	43	Under floor 4 – RHS near window
9	Ceiling 1 – LHS (near window)	44	Ceiling 4 – RHS near window
10	Ceiling 2 – RHS (near door)	45	Under roof 1 - near window
11	Ceiling 3 – LHS (near door)	46	Under roof 2 - near door
12	On Floor 1 – LHS (near window)	47	Roof ambient 2
13	On Floor – RHS (near door)	48	Column 1 at 0.01m
14	On Floor – LHS (near door)	49	Column 1 at 0.1m
15	On Floor – RHS (near window)	50	Column 1 at 0.6m
16	Wall 1 (RH) inside surface at 1 m	51	Column 1 at 1.1m
17	Wall 1 inside surface at 2m	52	Column 1 at 1.7m
18	Wall 1 outside surface at 1m	53	Column 1 at 2.1m
19	Wall 1 outside surface at 2m	54	Column 1 at 2.6m
20	Wall 1 external ambient at 2m	55	Column 1 at 2.69
21	Wall 2 inside surface at 1 m	56	Column 2 at 0.01m
22	Wall 2 inside surface at 2m	57	Column 2 at 0.1m
23	Wall 2 outside surface at 1m	58	Column 2 at 0.6m
24	Wall 2 outside surface at 2m	59	Column 2 at 1.1m
25	Wall 2 external ambient at 2m	60	Column 2 at 1.7m
26	Wall 3 (LHS) inside surface at 1	61	Column 2 at 2.1m
27	Wall 3 inside surface at 2m	62	Column 2 at 2.6m
28	Wall 3 outside surface at 1m	63	Column 2 at 2.69m
29	Wall 3 outside surface at 2m	64	Beam 1 Supply
30	Wall 3 external ambient at 2m	65	Beam 2 Supply
31	Wall 4 (Window) inside surface at	66	Beam 3 Supply
32	Wall 4 inside surface at 2m	67	Beam 1 Return
33	Wall 4 inside surface at 2.5m	68	Beam 2 Return
34	Wall 4 outside surface at 1m	69	Beam 3 Return

liquid. This pressure difference was then converted into a volume flow rate using appropriate charts.

6.3.1 Accuracy and calibration

The Dantec 54R10 anemometers have a quoted accuracy, for mean speeds, in the range 0.05 m/s to 1.0 m/s of ± 5% of the reading. The range of temperature measurement is quoted as 0 ^{o}C to 45 ^{o}C with an accuracy of ± 0.5 K. The Type T thermocouples are also quoted as having an accuracy of ± 0.5 K. The 1/10th DIN Pt100 sensors in the chilled water circuit are quoted as having an accuracy of 0.03 K at 0 ^{o}C. This higher degree of accuracy is valuable when measuring a temperature differential as small as 3 to 4 K.

Prior to commencement of the test programme, all the instruments were calibrated against the NAMAS accredited temperature sensor at BSRIA's Calibration Centre and wind tunnel facilities. The calibration drift for temperature and air speeds was calculated by regression analysis, from which formulae were derived and used to correct the measured data during the subsequent processing.

The resolution of the fluoro-carbon U-tube manometer was ± 1 mm H_2O (± 10 Pa), which equated to ± 0.001 kg/s for the commissioning set used.

6.4 Test procedure

The test procedure for evaluating the thermal environment in the modified room was similar to the procedure for the feasibility test. Prior to each test, the diffuser and ceiling type were installed and the respective air and water systems commissioned to ensure that the correct temperatures and flow rates were delivered to the test room. This involved balancing the air supply to each displacement terminal, and ensuring that the air extract rate was the same as the air supply rate.

The twelve Dantec 54R10 probes were mounted on two movable stands at heights of 0.1, 0.6, 1.1, 1.7, 2.1, and 2.6 m. The first four of these heights correspond to those prescribed by ASRAE (ASHRAE 55-1992) for thermal comfort measurement and relate to the occupied zone of the space. The furniture and heat gains were then placed in the rig at the appropriate locations.

The required heat gains were then activated, and the logging system started, scanning at intervals of three minutes. The facility was then operated continuously for several hours to allow temperatures to stabilise and steady state conditions to be reached. The system was judged to be at the equilibrium position when the temperatures in the environmental chamber were drifting by less than 0.2 ^{o}C per hour. In fact conditions were typically more stable than this with the total drift being less than 0.5 ^{o}C during a full test extending over 4 - 8 hours.

Once the equilibrium position had been established, the mobile instrument stands were moved to the first measuring points, and then left undisturbed for a period of 3 minutes before commencing data collection. The scanning period took a further three minutes, with readings being taken every 5 seconds. This time period had been found to be the best compromise between reliable estimates of average air speed, with effects of low frequency turbulence averaged out, and scanning time for building type applications as prescribed by ASHRAE (ASHRAE-55 1992).

At the end of the scan period, the data processed by the 54N10 multi-channel analyser was downloaded onto a PC. The instrument stands were then re-positioned to the next measurement point and left for a further 3 minute period, at the end of which the scanning process was repeated. The whole procedure was then repeated in this manner until the test had been completed.

6.4.1 Data analysis

The measured air speed and temperature data were stored as an ASCII file during the tests and subsequently analysed off-line. The figures were then imported into a spreadsheet and processed using a macro programme devised by the Microclimate Section at BSRIA. In this macro, the instrument calibration corrections were applied to the instrument results, and then mean air speeds and temperatures at each grid position and at all six points were calculated.

The results were also processed to assess the level of thermal comfort in the space. Use was made of Fanger's thermal comfort equation as described in ISO Standard 7730. This is an empirical relationship derived from subjective evaluations of thermal environments expressed as a value on a seven-point integer scale from –3 to +3. The equation gives a predicted mean vote, (PMV), for a particular set of environmental and occupant parameters – namely, air temperature, radiant temperature, air speed, relative humidity, clothing level and metabolic rate. This value is then used to derive a probable percentage dissatisfied (PPD) of a population of occupants, which is never less than 5% due to individual preferences.

The calculations incorporated the following assumptions:

- Metabolic rate = 1.2 mets or 70 W/m^2 of body surface area.
- No external work, so all metabolic output is converted to body heat.
- Clothing insulation = 0.6 clo, 0.093 m^{2}K/W, typical summer clothing ensemble.
- Relative humidity = 50 %.

Additionally, the percentage of the population being bothered by draught was predicted using the following equation, also from ISO Standard 7730:

$$DR = (34 - t_a)(v - 0.05)^{0.62}(0.7 \times v \times T_u + 3.14)$$

Where: DR = Draught risk

t_a = the local air temperature (^{o}C).

v = the local mean air velocity (m/s)

T_u = the local turbulence intensity, defined as the ratio of the standard deviation of the instantaneous velocity divided by the time averaged mean. This is recorded automatically by the 54N10 multi-channel analyser.

Finally, the macro calculated the air diffusion performance index (ADPI) as defined in ASHRAE Standard 55-1992. The ADPI indicates the uniformity of the conditions in the space. This takes into account the influence of an effective draught temperature that is a function of local air velocity and temperature, and mean room temperature. This parameter is probably less appropriate for displacement ventilation techniques, where uniformity is not a design intention.

In using PMV and PPD as indicators, it is acknowledged that there is some debate over their accuracy or validity in predicting thermal comfort, (Oseland 1993, 1994 and 1995, Fanger 1995, Alfano 1995, Humphreys 1998), despite their widespread use in setting standards (Bunn 1993). However, their use here is to give an indication of the relative performance of different systems in terms of comfort rather than an absolute prediction of thermal comfort.

6.4.2 Experimental programme

The object of the experimental programme is to compare the performance of the textile diffuser with the performance of a perforated bin diffuser with supplementary cooling devices at cooling loads up to 53 W/m^2.

The experiments were planned as follows:

Experiment 1 – Cooling load 17 W/m^2, air change rate of 3 per hour via textile diffuser

These experimental data were used to confirm the limitations of displacement ventilation only at an air change rate of 3 per hour (45.6 l/s).

Experiment 2 – Cooling load 53 W/m^2, air change rate of 6 per hour, (91.13 l/s) via textile diffuser.

The object of this part of the experimental programme is to assess the effectiveness of increasing air flow rate to balance increased heat load and to evaluate the overall thermal comfort performance of this method of delivery using the Fanger thermal comfort criteria as set out in ISO 7730 1995.

Experiment 3 – Cooling load 53 W/m^2, air change rate of 9 per hour, (136.7 l/s) via textile diffuser.

These experimental data were used to assess the effectiveness of increasing air flow rate to balance increased heat load and to evaluate the overall thermal comfort performance of this method of delivery using the Fanger thermal comfort criteria as set out in ISO 7730 1992.

The results of this experiment were used to verify the results of the feasibility study in the original test room.

Experiment 4 – Cooling load 53 W/m^2, air change rate of 3.5 per hour (53.16 l/s) via two Halton LBV100 diffuser supplemented by chilled ceiling panels at 14 °C.

This experimental data provided a reference point for performance comparisons. It is an arrangement that is being widely adopted commercially (Butler 1997), and is one of the arrangements to be included in the BSRIA Code of Practice on Displacement Ventilation with static cooling devices (BSRIA COP 17/99).

6.5 The modified test room

This section provides a photographic illustration of the modified test facility to supplement the information provided by diagrams earlier in this chapter (see Figures 6.1, 6.2, and 6.3).

The hardboard lined outer enclosure, which formed the original 10 m by 6 m test room where the preliminary tests were carried out was located at one end of a hangar style building housing a number of independent test rigs (see Figure 6.4). The modified test room for the subsequent experimental work was built within this enclosure. This provided a more stable environment than the building in which the rig is located. On the left of the figure, obscuring some of the instrumentation, the supply ductwork for an adjacent test room can be seen, illustrating the cramped nature of the test facility. It was this multiple use of the building that sometimes caused problems with the temperature stability in the space around the test room. The steps to the entrance give an indication of the raised floor that was used to route the ductwork for the displacement ventilation diffusers.

Figure 6.4 Entrance to test room

The Dantec 54N10 multi-channel flow analyser and the Hewlett Packard 75000 series B data logger and their associated PCs were originally located at the front of the test room to the left of the entrance door (see Figure 6.5). The room heat balance information could be monitored at this station to ensure steady state before commencing each data

Figure 6.5 Data acquisition equipment

run. For the tests in the modified internal room, the equivalent equipment was moved into the 10 m by 6 m enclosure, adjacent to the modified room entrance for ease and speed of operation.

Artificial PCs were made for use in the adapted test room (see Figure 6.6). The casing is 1 mm plate steel shaped as a PC and painted light grey to emulate the radiative properties of a typical PC. The heat output is generated by a 150 W tungsten lamp within the casing. This is representative of a typical PC load, (Parsloe C 1992). The original test room used real PCs but the internal fan units were found to significantly distort the velocity readings at desktop height. A total of four artificial PCs were available in the room.

Figure 6.6 Equipment within the test room

The original artificial bodies located at each workstation were re-used in the modified test room (see Figure 6.7). These were constructed from 1.5 mm plate steel, painted matt black on the external surface, optimising radiant heat emission. The heat output is generated by a 100 W tungsten lamp within the casing. This approximates to the sensible heat gain of a lightly active person undertaking office work at an ambient dry bulb temperature of 20 °C. A total of two artificial occupants were available in the room.

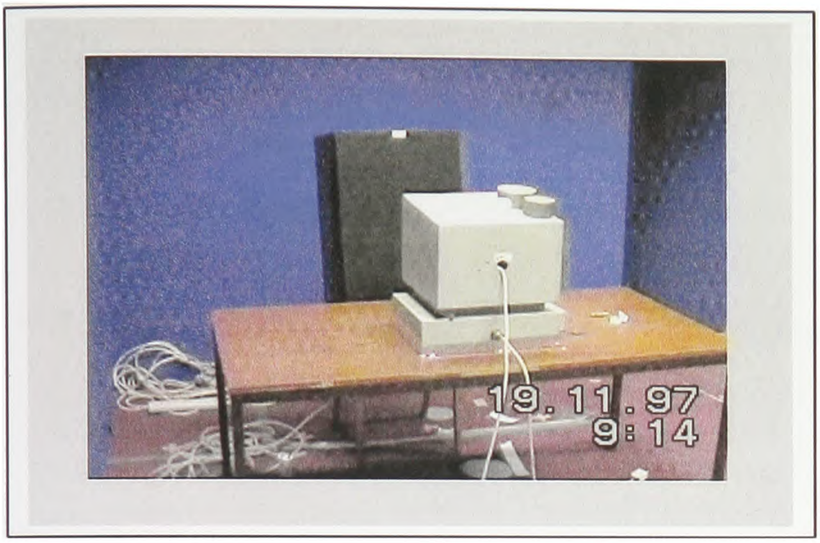


Figure 6.7 Equipment and 'occupant' within the test room

One wall of the chamber was fitted with double glazing to the outdoor environment simulator zone (see Figure 6.8). This zone was equipped so that different external temperatures could be simulated if required. This facility was not required for the fabric diffuser tests carried out, it simply assisted in the process of maintaining a stable thermal environment around the test room during the experiments. The glazing is 1.2 m high and runs the full 4.5 m width of the room.

Figure 6.8 Glazed wall

To simulate, when required, a range of outdoor conditions, refrigeration units were provided (see Figure 6.9) to treat the space beyond the test room glazing

Figure 6.9 Refrigeration unit for outdoor environment simulator

Adjustable mobile stands were used fitted with brackets to support the arrays of six Dantec 54R10 probes at heights of 0.1, 0.6, 1.1, 1.7, 2.1, and 2.6 m (see Figure 6.10). The stand also supported two thermocouples incorporated within matt black spherical globes mounted at 0.6 and 1.1 m to measure dry resultant temperature, which in combination with the air temperature and air speeds allowed the radiant temperature to be calculated. There were two mobile arrays used to collect the experimental data.

Figure 6.10 Mobile stand

The basic air handling unit used to control the temperature of the ventilation supply air for the original test room (see Figure 6.11) was replaced with a more sophisticated unit for the subsequent experimental programme. The system comprised a centrifugal fan, chiller and expansion coil, an electric heater battery and a Eurotherm controller for controlling heat emission from the battery, and hence the supply air temperature. A damper at the fan inlet was used to regulate the air volume flow rate through the system, and an AMCA Standard 50 mm nozzle box was used to measure the air volume flow rate.

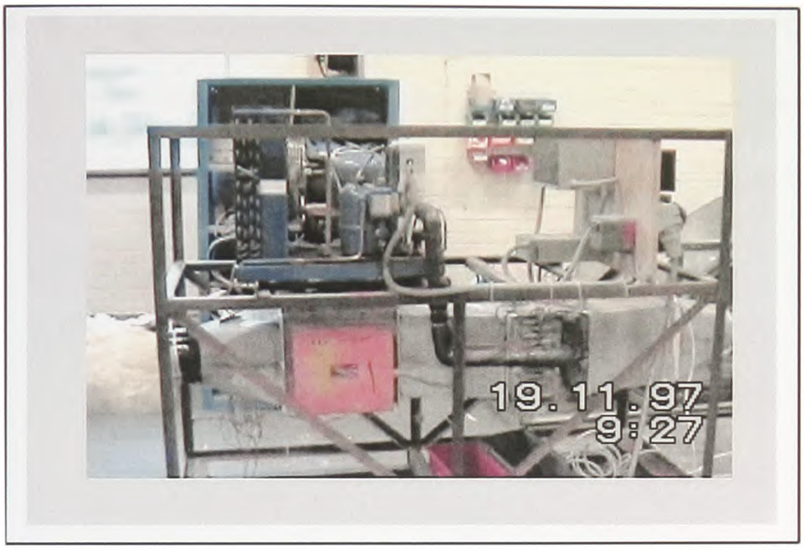


Figure 6.11 Supply air handling unit for original test room

The new air handling unit for the modified test room is shown in Figure 6.12. The unit incorporated a proportional controller regulation system. Air was extracted at the same rate as the supply rate to give a zero pressure differential between the test room and the outer shell, keeping infiltration/exfiltration to a minimum. This unit has been designed to give close control of temperature and humidity, using a Landis and Staefa 'Integral AS1000'

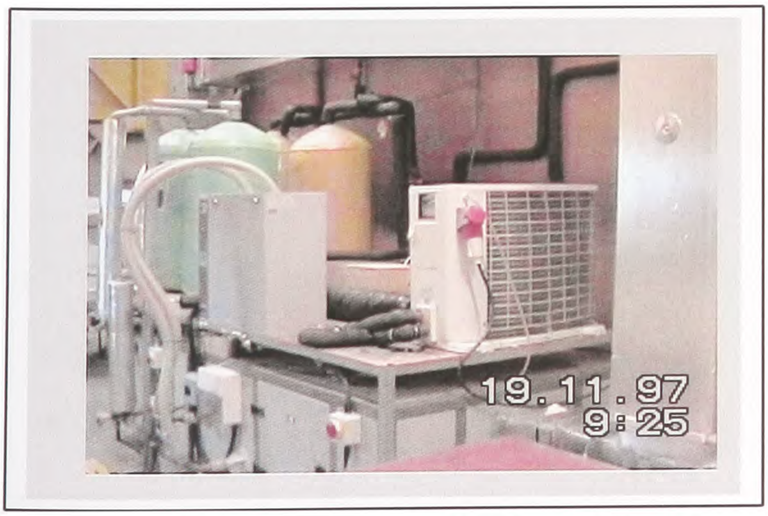


Figure 6.12 Air handling unit for the modified test room

building management system, and was incorporated into the rig in preparation for a CIBSE sponsored research project to investigate the condensation risk associated with chilled beams, (A Martin 1997).

The chilled water storage arrangement for the modified test room is shown in Figure 6.13. The chilled water circuit delivered water at 14 °C to the panels with a mass flow rate of 0.0554 kg/s provided by means of a water-to-water refrigeration system. Primary water was pumped from a chiller to a heat exchanger coupled to the secondary water circuit that supplied the chilled ceiling panels.

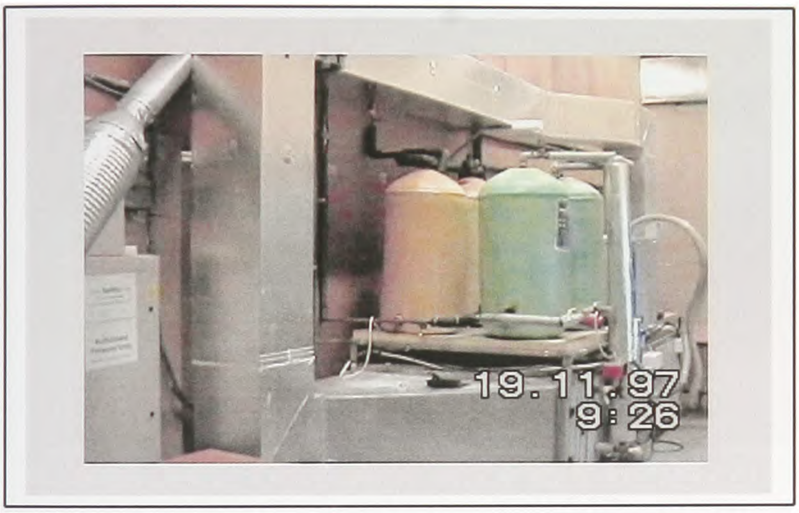
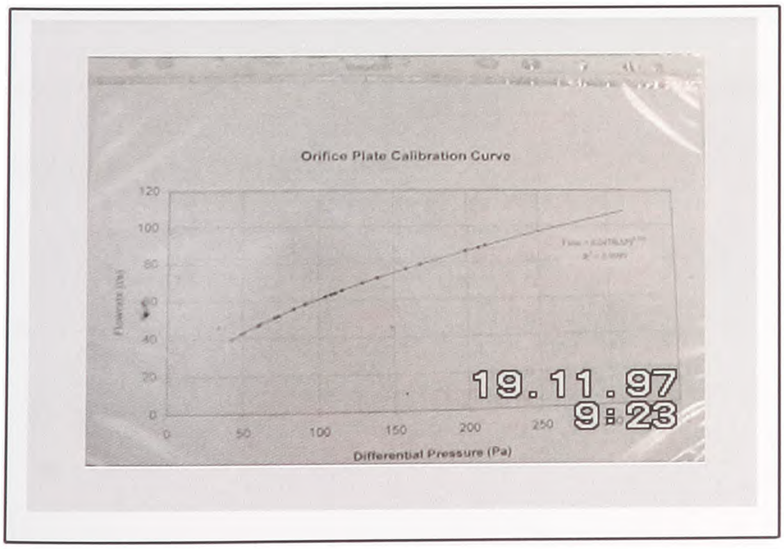


Figure 6.13 Chilled water rig for modified test room

For all experiments, an orifice plate calibration curve was used to confirm the air volume flow rate through the system (see Figure 6.14). A 50 mm AMCA Standard Nozzle Box, (AMCA Standard 500-89), was fitted in the supply duct work and the differential pressure measured using an electronic hand held



6.14 Orifice plate calibration curve

pressure differential meter. This reading was then converted to flow rate (l/s) using the calibration curve, that was produced by the NAMAS accredited Calibration Centre at BSRIA, Bracknell.

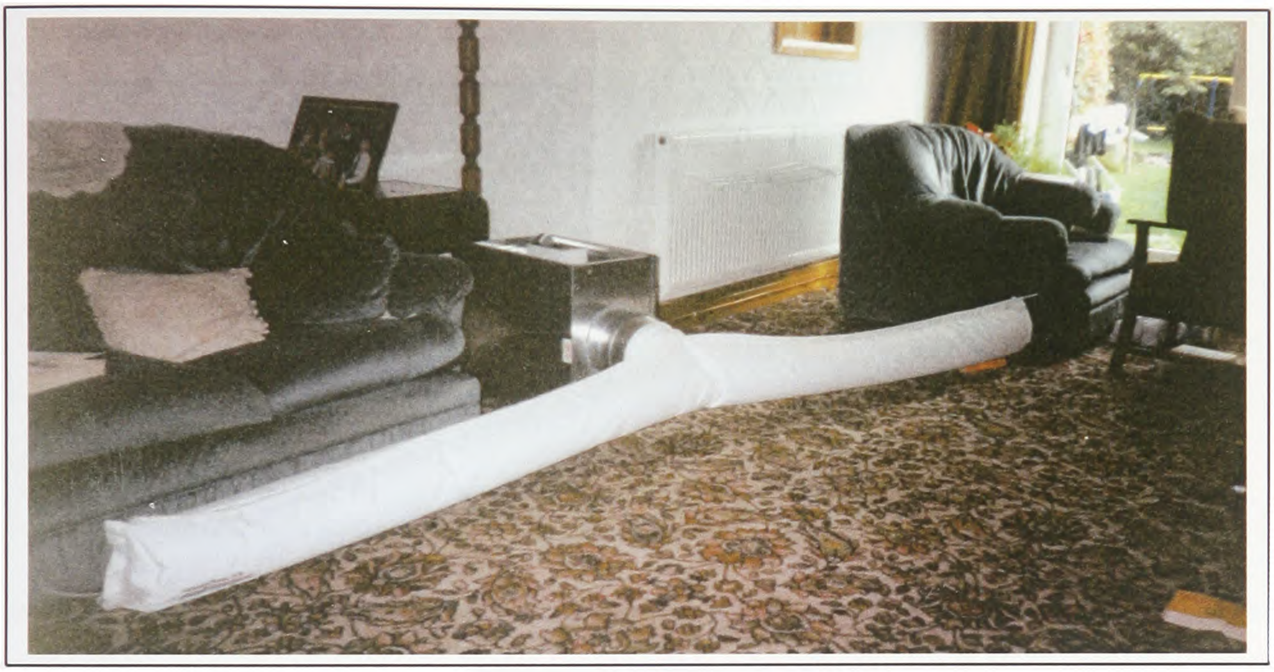


Figure 6.15 Demonstration textile diffuser equipment

A portable demonstration textile diffuser and fan unit was manufactured for Hoare Lea & Partners to assist them in explaining the technique to potential clients. The author used the unit when presenting a paper at Conference (Geens 1997), to demonstrate the techniques to the delegates.

6.6 Analysis of experimental results

The comparative performance of the experimental situations considered (Section 6.4.2) is tested against the following criteria taken from ISO 7730 1995:

i) Air temperature not to exceed 26 °C.

ii) Vertical temperature gradient not to exceed 3 K from ankle to head (approximately 3 K/m sitting).

iii) Air velocity less than 0.15 m/s in winter, 0.25 m/s in summer.

iv) PMV between – 0.5 and + 0.5.

v) PPD less than 10.

For each experiment, room profiles are shown for average temperature, average velocity, average PMV and average PPD. Full details of recorded data are included in Appendix II. Table 6.3 summarises the key results from the programme of experiments.

Table 6.3 Summary of averaged results for experiments 1 - 4

	Experiment 1	Experiment 2	Experiment 3	Experiment 4
Temperature at head height (sitting) °C	26.2	27.1	23.5	23.8
Temperature at head height (standing) °C	26.6	28.8	25.6	23.9
Temperature Gradient (sitting) K	2.8	4.6	2.9	2.9
Temperature Gradient (standing) K	3.2	6.3	5	3.0
Air Velocity m/s Max	0.1	0.08	0.08	0.1
PMV Sitting/standing	0.6/0.67	0.89/1.145	-0.02/0.33	-0.09/-0.08
PPD % Sitting/standing	12.7/14.5	21.9/32.8	5.1/7.3	5.3/5.3

6.6.1 Experiment 1

The room was set up with a cooling load of 17 W/m^2, and an air change rate of 2.7 per hour via textile diffuser.

Although this experiment was intended to study the performance of an air flow rate of 45.6 l/s or 3 air changes per hour, an air leak on the supply ductwork was discovered after the data had been collected. Based on experience of earlier test programmes, suspicion was raised, as the room air temperatures were a little higher than expected. By studying the energy balance data collected it was possible to deduce that the actual air flow rate delivered was 41 l/s or 2.7 air changes per hour. The leak was repaired and the same energy balance check was carried out for each subsequent experiment to ensure that the measured air flow rate was actually being delivered to the room, which proved to be the case.

Considering each of the comfort criteria above in turn:

i) Air temperature not to exceed 26 °C.

The average temperature profile, Figure 6.16, indicated that the temperature in the room rapidly rises from 23.4 °C to 26.2 °C at seated head height of 1.1 m, and at standing head height is 26.6 °C.

ii) Vertical temperature gradient not to exceed 3 K from ankle to head (approximately 3 K/m sitting).

The temperature gradient, ankle to head, is from 23.4 °C to 26.2 °C at sitting head height, i.e. 2.8 K. For standing occupants the gradient, ankle to head is from 23.4 °C to 26.6 °C, i.e. 3.2 K.

iii) Air velocity less than 0.15 m/s in winter, 0.25 m/s in summer.

As indicated in Figure 6.17, there were no air velocities in the room recorded above 0.15 m/s, the maximum recorded value was 0.1 m/s.

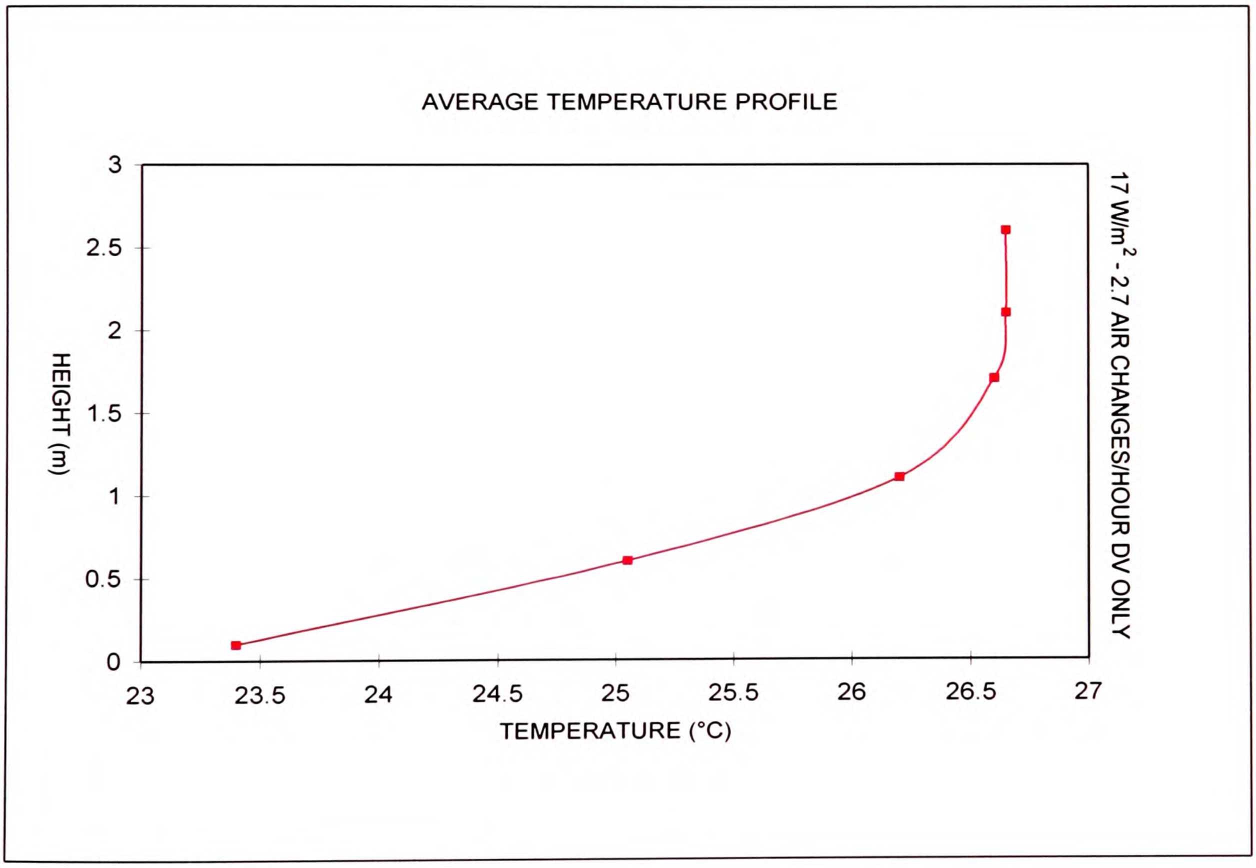


Figure 6.16 Experiment 1 – Average temperature profile

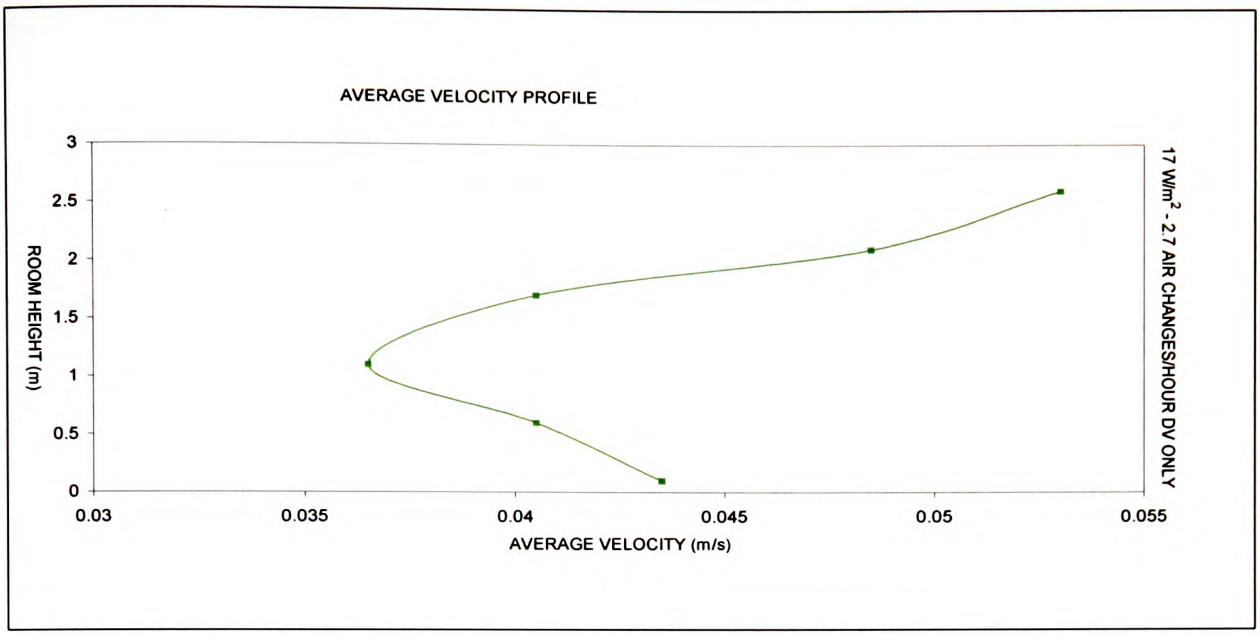


Figure 6.17 Experiment 1 – Average velocity profile

iv) PMV between – 0.5 and + 0.5.

The profile for average PMV, Figure 6.18, is entirely positive, which is the warm side of neutral, and appears very similar to the average temperature profile. This indicates that the comfort index is being influenced predominantly by temperature. At sitting head height, the average PMV is already 0.601 and outside acceptable limits.

iv) PPD less than 10.

As the PPD value is derived from the PMV, the profile, Figure 6.19, also shows values outside acceptable limits with 12.7% of seated occupants predicted to be uncomfortably warm, and 14.5% of standing occupants predicted to be uncomfortably warm.

The analysis of these results shows the environmental control system failing when considering averaged values. As these values will be concealing extremes, it is reasonable to assume, without detailed examination of the full data, that even worse conditions occur locally within the space.

This failure is marginal; although the temperature is high, the temperature gradient is acceptable, and it could be conjectured that at the planned air supply rate of 3 air changes per hour the conditions would have been even closer to being acceptable. The objective of this experiment was to demonstrate that as cooling loads approach 20 W/m^2 with an air change rate of 3.5 per hour, a displacement ventilation system alone will struggle to maintain acceptable environmental comfort conditions. With the air supply rate reduced below 3.5 per hour, for a 17 W/m^2 cooling load these results clearly support this.

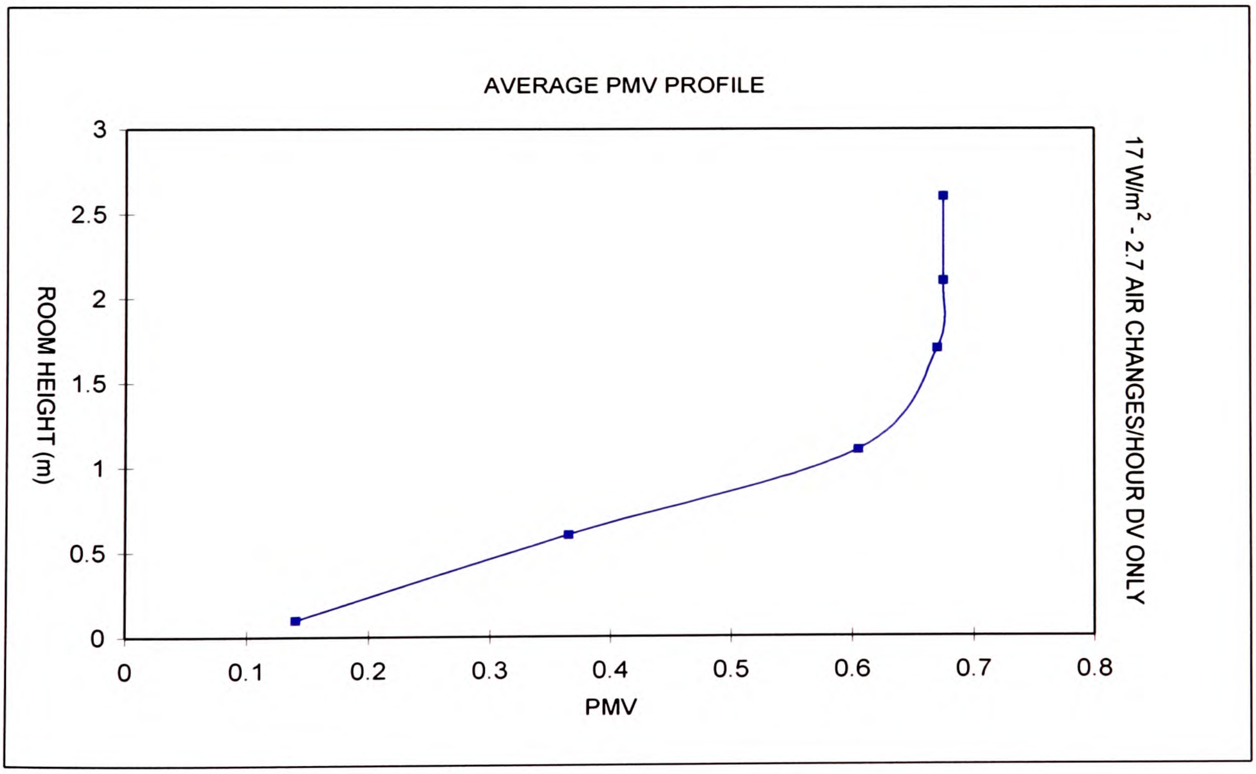


Figure 6.18 Experiment 1 – Average PMV profile

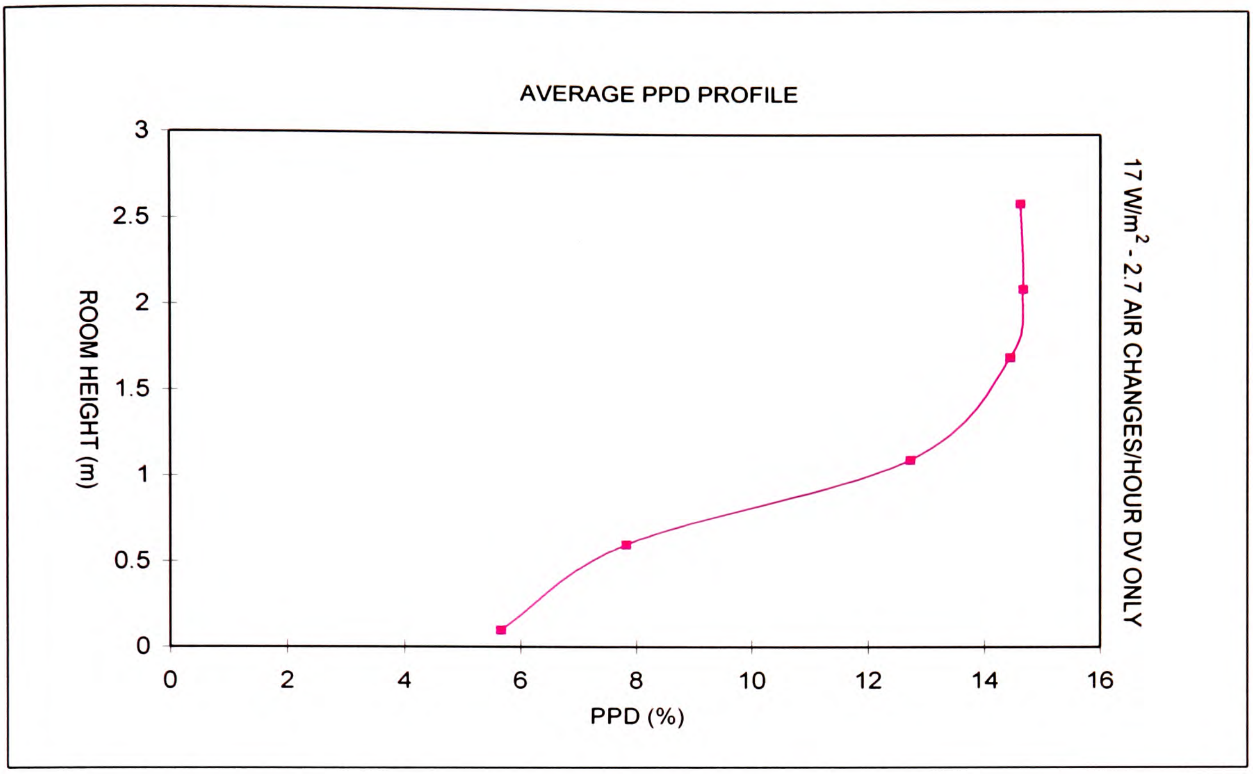


Figure 6.19 Experiment 1 – Average PPD profile

6.6.2 Experiment 2

The room was set up with a cooling load of 53 W/m^2, and an air change rate of 6 per hour, (91.13 l/s) via textile diffuser. The cooling load was increased to 53 W/m^2, the figure that had been selected to represent a typical office situation. The indications from the feasibility study, (Section 5.0), were that the textile diffusers used for displacement ventilation delivery could effectively control the thermal environment for this scale of cooling load if a high air change rate was used (9.3 per hour). This meant that it would not be necessary to conduct a series of experiments for cooling loads between 17 and 53 W/m^2. The extent to which the air change rate needed to be raised to deal with such a load did need to be addressed and so this experiment would investigate performance at the intermediate rate of 91.13 l/s or 6 air changes per hour.

This rate is considered to be the maximum for other conventional diffuser types (BSRIA COP 17/99). Considering each of the comfort criteria above in turn:

i) Air temperature not to exceed 26 ^{o}C.

The average temperature profile, Figure 6.20, indicated that temperature in the room rises rapidly from 22.5 ^{o}C to 27.1 ^{o}C at seated head height of 1.1 m, and at standing head height is 28.8 ^{o}C.

ii) Vertical temperature gradient not to exceed 3 K from ankle to head (approximately 3 K/m sitting).

The temperature gradient, ankle to head, is from 22.5 ^{o}C to 27.1 ^{o}C respectively at sitting head height, i.e. 4.6 K. For standing occupants the gradient, ankle to head is from 22.5 ^{o}C to 28.8 ^{o}C respectively, i.e. 6.3 K.

iii) Air velocity less than 0.15 m/s in winter, 0.25 m/s in summer.

As shown in Figure 6.21, there were no average air velocities in the room recorded above 0.15 m/s, however, a maximum recorded value of 0.2 m/s was indicated at a height of 0.1 m. An examination of the detailed data in Appendix II reveals that this was the only reading taken that was in excess of 0.15 m/s, and was one of the points where the probe was pressed into the textile diffuser close to the air supply connection. An occupant of the room would not experience this.

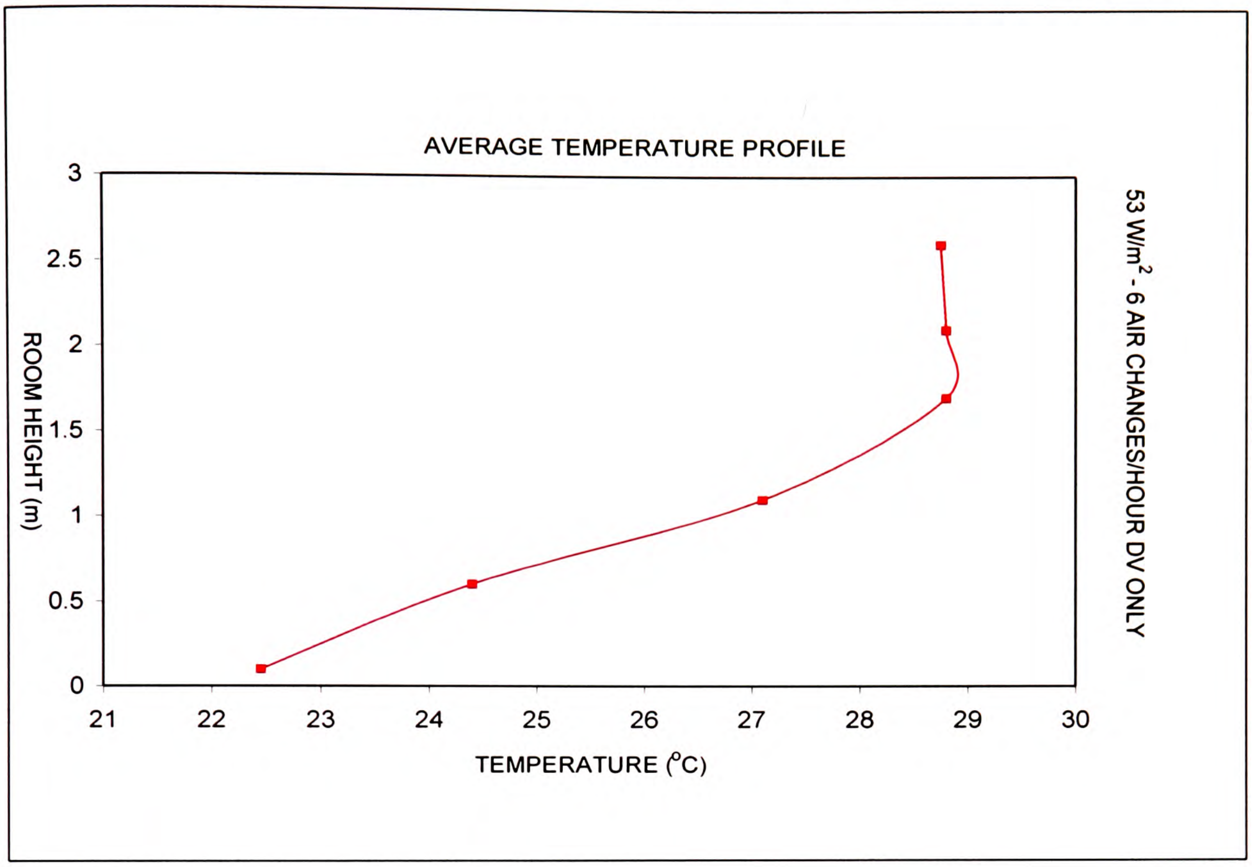


Figure 6.20 Experiment 2 – Average temperature profile

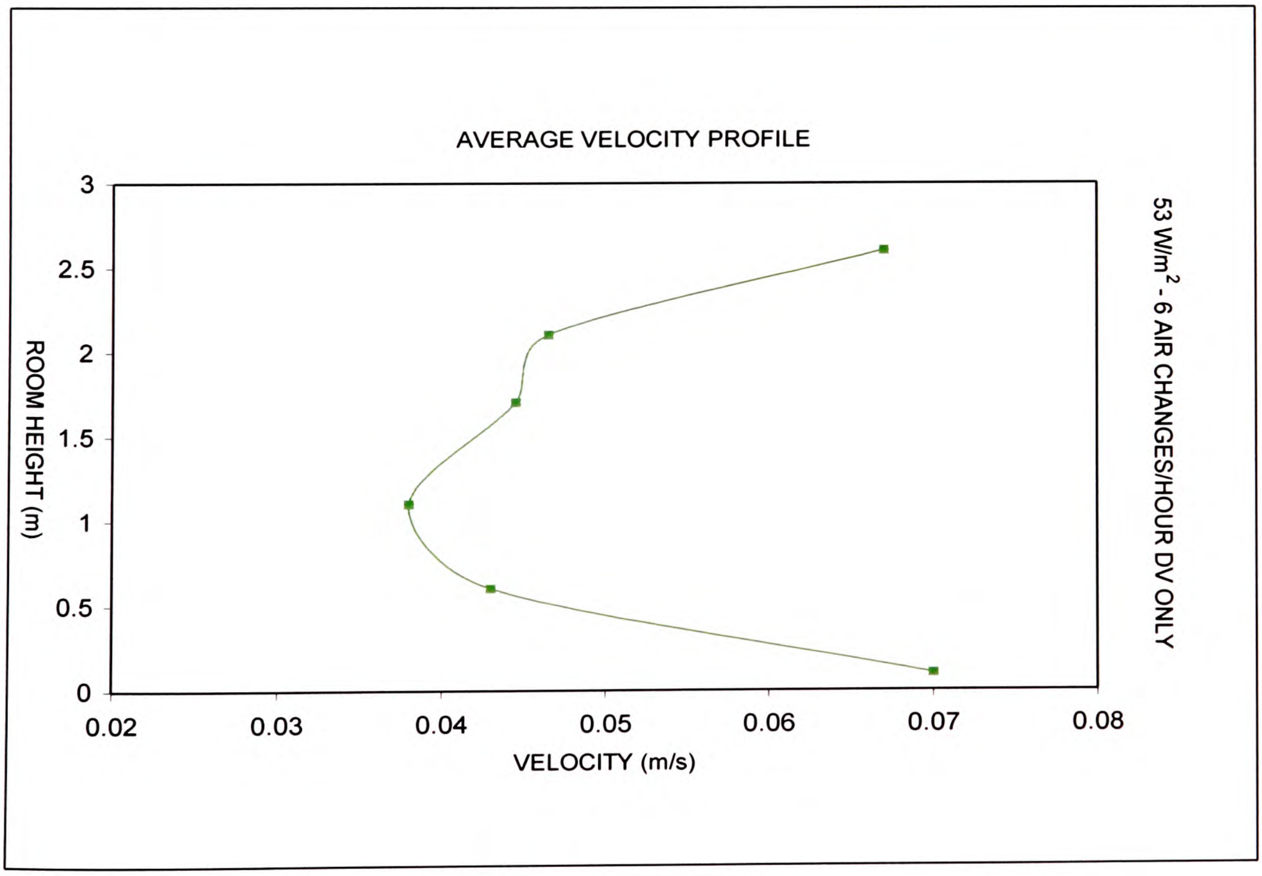


Figure 6.21 Experiment 2 – Average velocity profile

iv) PMV between – 0.5 and + 0.5.

The profile for average PMV, Figure 6.22, is entirely positive, which is the warm side of neutral, and appears very similar to the average temperature profile. This suggests that the comfort index is being influenced predominantly by temperature. At sitting head height, the average PMV is already 0.89 and outside acceptable limits.

v) PPD less than 10.

As the PPD value is derived from the PMV, the profile, Figure 6.23, also shows values outside acceptable limits with 21.9% of seated occupants predicted to be uncomfortably warm, and 32.8% of standing occupants predicted to be uncomfortably warm.

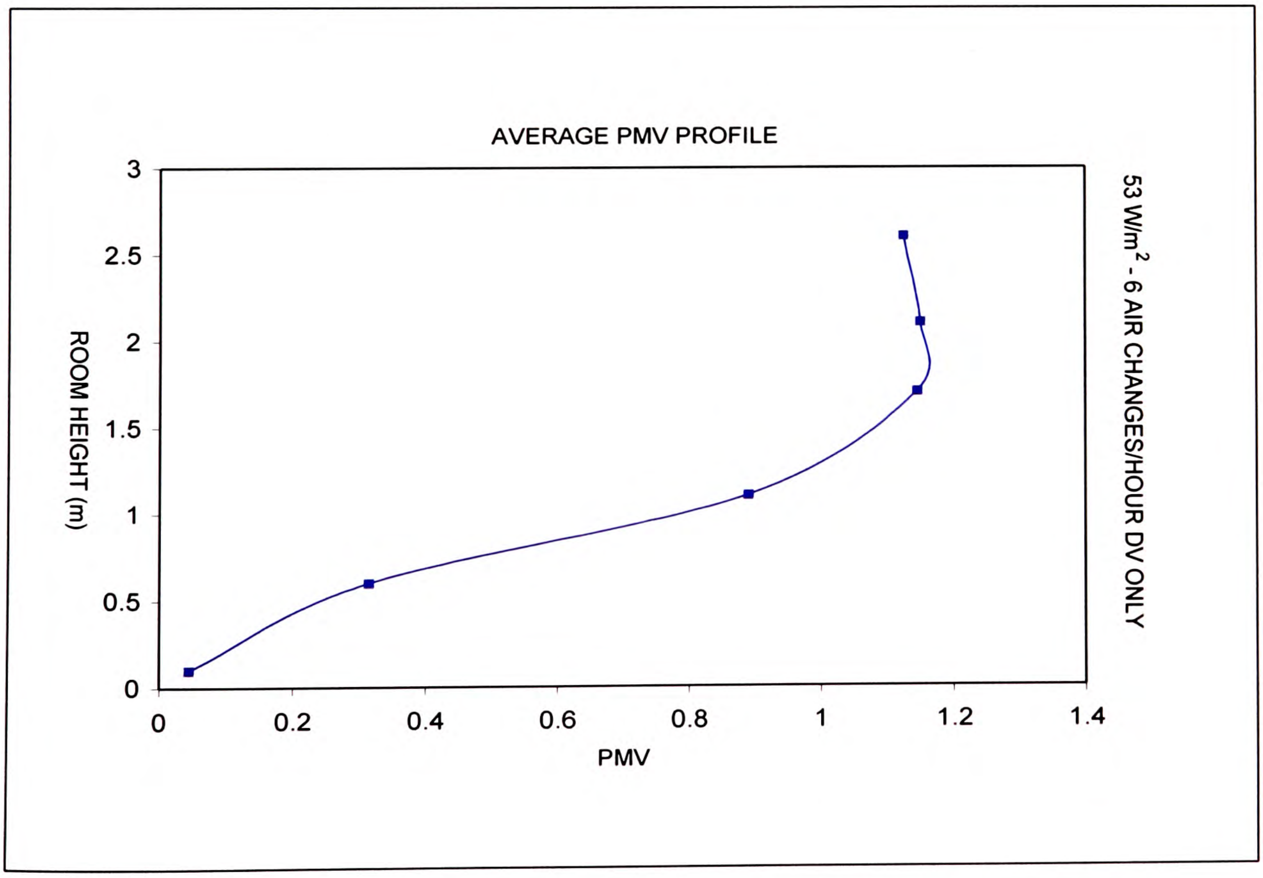


Figure 6.22 Experiment 2 – Average PMV profile

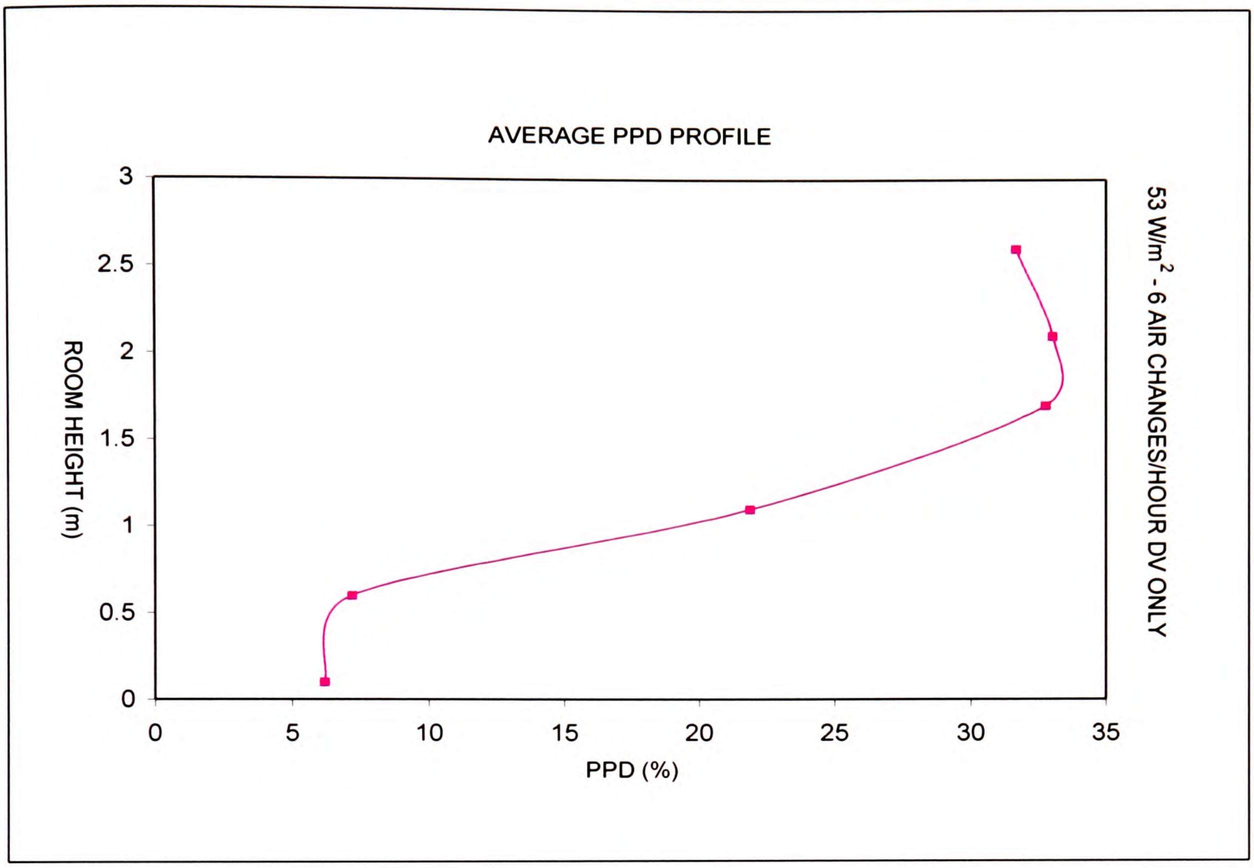


Figure 6.23 Experiment 2 – Average PPD profile

The analysis of these results shows the environmental control system failing when considering averaged values. As these values will be concealing extremes, it is reasonable to assume that even worse conditions occur locally within the space without detailed examination of the full data. A further increase in airflow rate is required.

When entering the test room to move the mobile sensor stands, it was evident that the temperatures were unacceptably high. In anticipation that these results would demonstrate an unsatisfactory thermal environment, readings were taken on an alternate grid line basis to save time, as full grid accuracy would only be necessary once comfort conditions were being approached.

6.6.3 Experiment 3

The room was set up with a cooling load of 53 W/m^2, and an air change rate of 9 per hour, (136.7 l/s) via textile diffuser.

This experiment, with the increased air flow rate of 9 air changes per hour and cooling load of 53 W/m^2, is very similar to the conditions investigated in the feasibility study. If the results do not demonstrate that thermal comfort is being achieved, the results of the feasibility study will be challenged.

Considering each of the comfort criteria above in turn:

i) Air temperature not to exceed 26 ^{o}C.

The average temperature profile, Figure 6.24, indicated that temperature in the room gradually rises from 20.4 ^{o}C to 23.5 ^{o}C at seated head height of 1.1 m, and at head height is 25.6 ^{o}C. An examination of the detailed data in Appendix II reveals that the highest temperature recorded in the occupied zone is 25.8 ^{o}C at 1.7 m. The minimum temperature recorded at the same height is 25.3 ^{o}C, which, with an average of 25.6 ^{o}C suggests a particularly uniform air flow regime with stable conditions across the occupied space. The same uniformity is not apparent at 0.1 m. Here the minimum value of 18.3 ^{o}C is considerably below the average of 20.4 ^{o}C.

ii) Vertical temperature gradient not to exceed 3 K from ankle to head (approximately 3 K/m sitting).

The temperature gradient, ankle to head, is from 20.6 °C to 23.5 °C respectively at seating head height, i.e. 2.9 K. For standing occupants the gradient, ankle to head is from 20.6 °C to 25.6 °C respectively, i.e. 5.0 K

.

iii) Air velocity less than 0.15 m/s in winter, 0.25 m/s in summer.

As shown in Figure 6.25 there were no average air velocities in the room recorded above 0.15 m/s, although a maximum recorded value of 0.2 m/s was indicated at a height of 0.1 m. An examination of the detailed data in Appendix II reveals that this was the only reading taken that was in excess of 0.15 m/s, and was one of the points where the probe was pressed into the textile diffuser close to the air supply connection. An occupant of the room would not experience this.

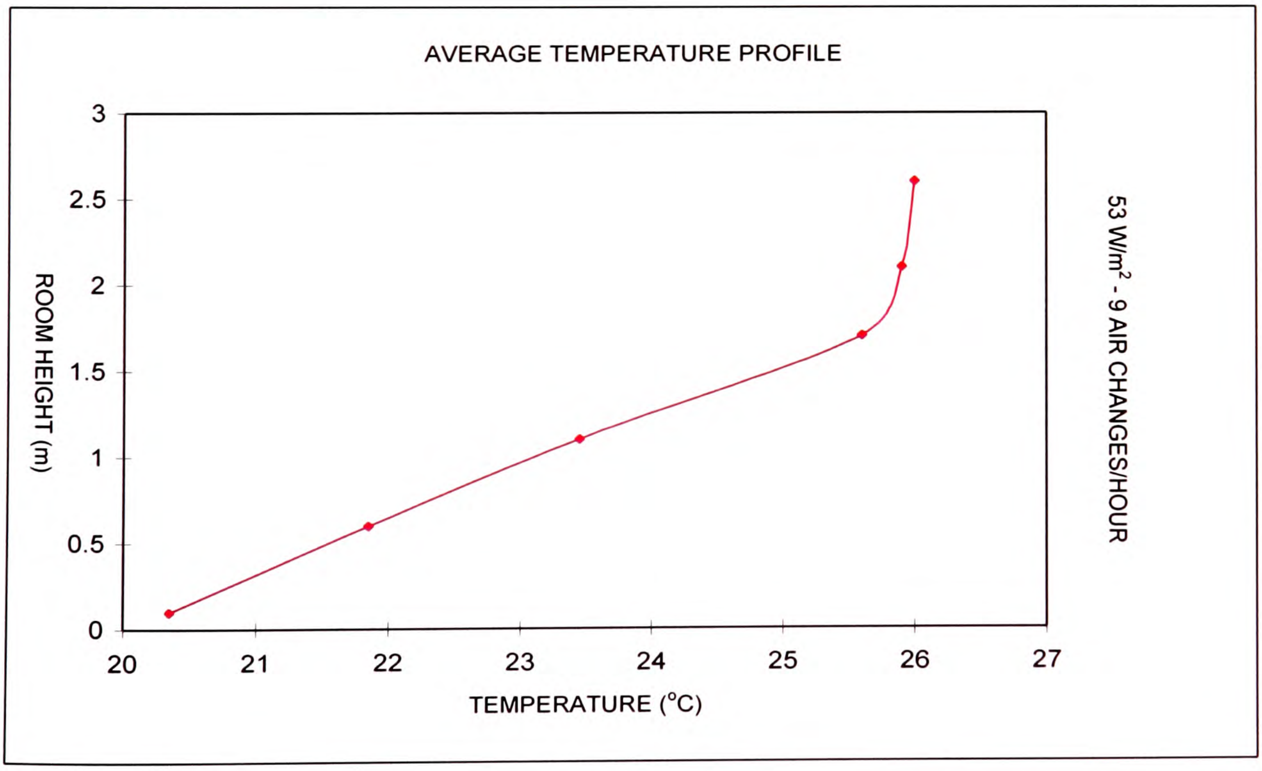


Figure 6.24 Experiment 3 – Average temperature profile

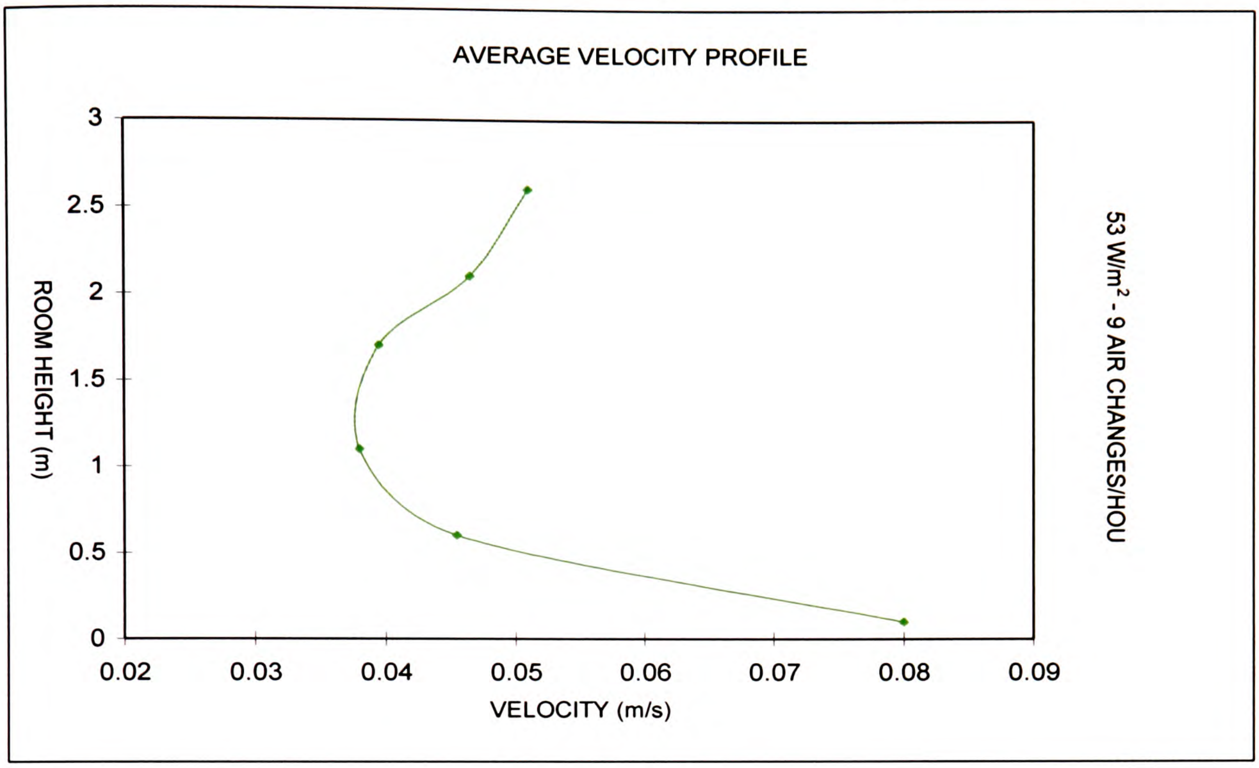


Figure 6.25 Experiment 3 – Average velocity profile

iv) PMV between – 0.5 and + 0.5.

The profile for average PMV, Figure 6.26, is – 0.6 at feet level rising to – 0.02 at seated head height and 0.33 at standing head height, i.e. slightly too cool at the feet, neutral at the head sitting, and slightly warm at the head standing. The absence of high velocities again indicates that the comfort index is being influenced predominantly by temperature.

iv) PPD less than 10.

As the PPD value is derived from the PMV, the profile, Figure 6.27, also shows values outside acceptable limits with 12.4% of occupants predicted to be uncomfortably cool at feet level. When temperature and velocity are considered alone, these results show that comfortable conditions are being maintained in the test room. Although this confirms the findings of the feasibility study, this is an oversimplified appraisal. When temperature gradient, PMV and PPD are considered, conditions are shown to be less acceptable. The temperature gradient for a seated occupant is just within tolerance, but is excessive for standing occupants. PMV and PPD indicate an unacceptably cool area at feet level. The problem with the temperature gradient is not that the temperature is too high at the top of the occupied zone, rather that the temperature is too low at the bottom of the occupied zone. The degree by which tolerances are exceeded are relatively small and the conclusions to be drawn from these results will be developed in Chapter 9.

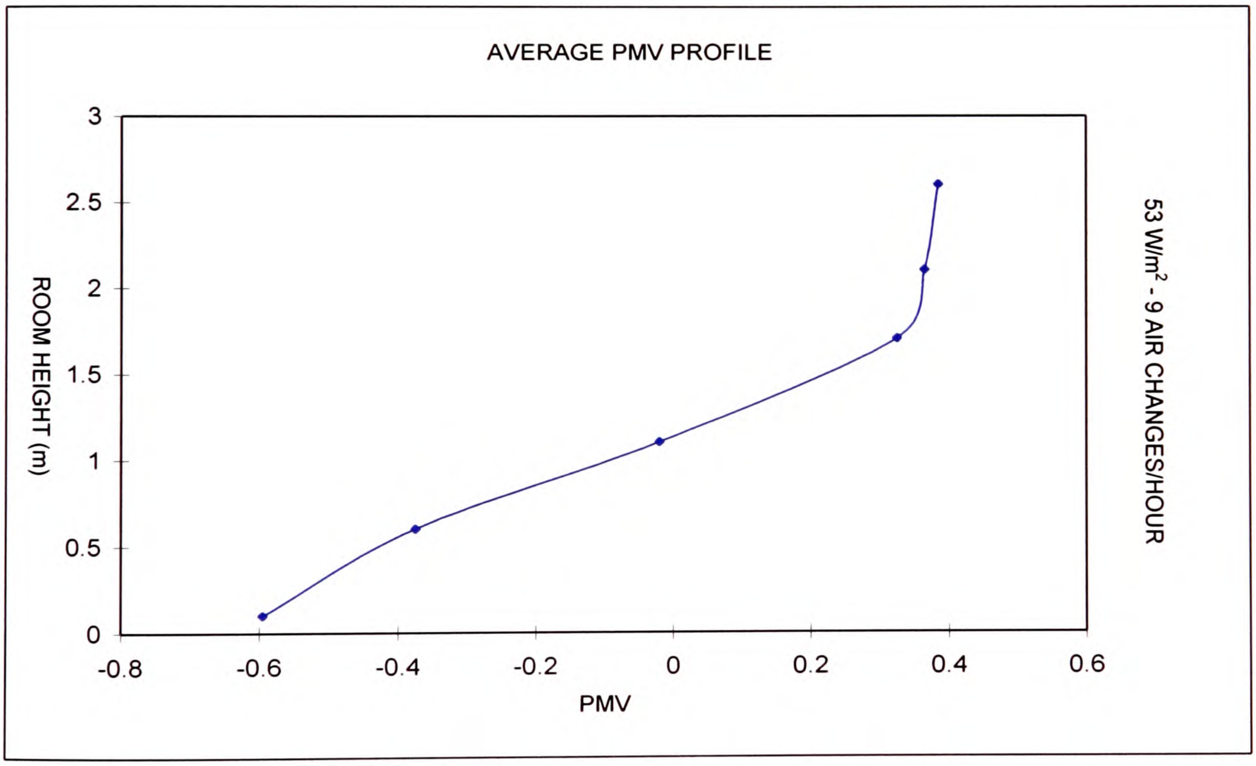


Figure 6.26 Experiment 3 – Average PMV profile

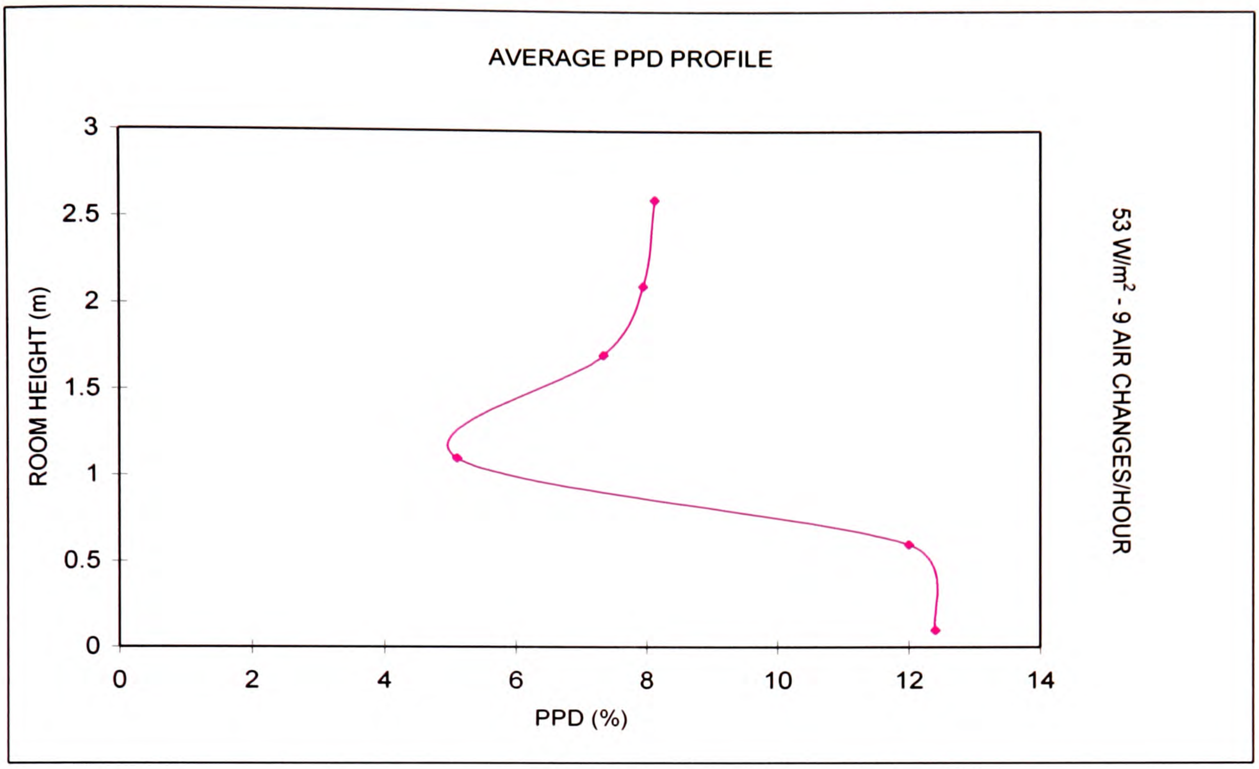


Figure 6.27 Experiment 3 – Average PPD profile

6.6.4 Experiment 4

The room was set up with a cooling load of 53 W/m^2, and an air change rate of 3.5 per hour (53.16 l/s) via Halton LBV100 diffuser supplemented by chilled ceiling panels at 14 °C.

In using PMV and PPD as indicators, it has been acknowledged in Section 6.4 that there is some debate over their accuracy or validity in predicting absolute thermal comfort, (Humphreys M 1998). This experiment will provide data for the 53 W/m^2 cooling load being treated by a displacement ventilation/chilled ceiling panel combination that has been identified as typical of current commercial practice, to allow the relative performance of the arrangement in Experiment 3 to be assessed.

Considering each of the comfort criteria above in turn:

i) Air temperature not to exceed 26 °C.

The average temperature profile, Figure 6.28, indicated that temperature in the room gradually rises from 20.9 °C to 23.8 °C at seated head height of 1.1 m, and at standing head height is 23.9 °C.

ii) Vertical temperature gradient not to exceed 3K from ankle to head (approximately 3K/m sitting).

The temperature gradient, ankle to head, is from 20.9 °C to 23.8 °C respectively at sitting head height i.e. 2.9K. For standing occupants, the gradient ankle to head is from 20.9 °C to 23.9 °C respectively, i.e. 3.0K.

iii) Air velocity less than 0.15 m/s in winter, 0.25 m/s in summer.

As shown in Figure 6.29, there were no average air velocities in the room recorded above 0.15 m/s, however, a maximum recorded value of 0.17 m/s was indicated at a height of 2.6 m, i.e. above the occupied zone. An examination of the detailed data in Appendix II reveals that there were 8 readings taken that were in excess of 0.15 m/s, but only two of these, each at 0.16 m/s were in the occupied zone both at a height of 1.7 m.

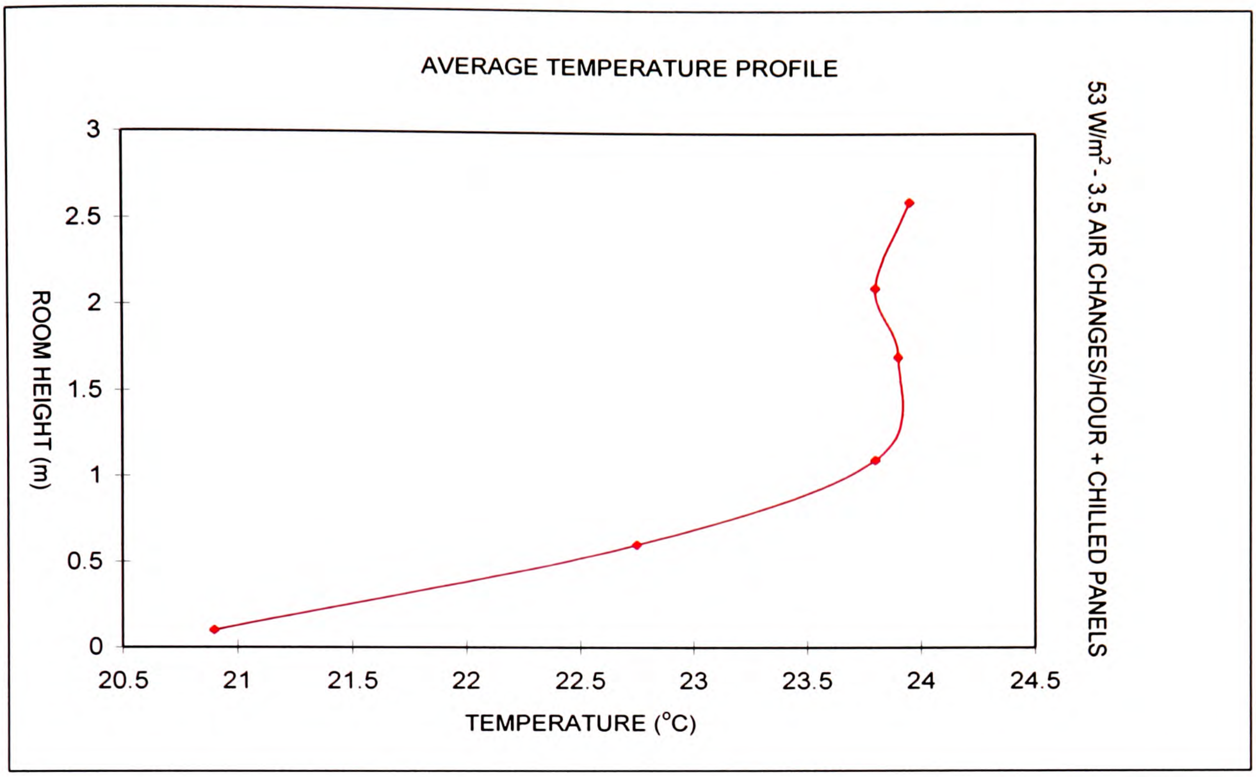


Figure 6.28 Experiment 4 – Average temperature profile

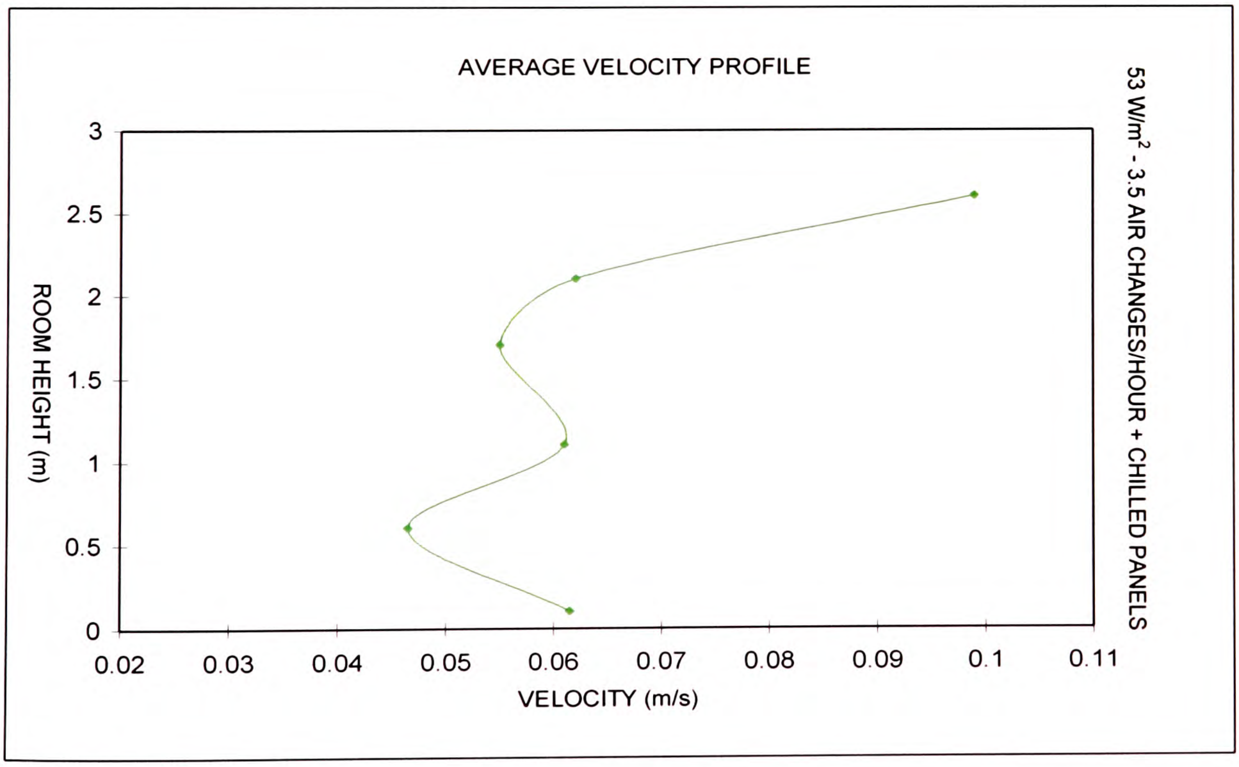


Figure 6.29 Experiment 4 – Average velocity profile

iv) PMV between – 0.5 and + 0.5.

The profile for average PMV, Figure 6.30, is – 0.61 at feet level rising to – 0.09 at seated head height and - 0.08 at standing head height, i.e. slightly too cool at the feet and approaching neutral from cool, at the head sitting, and standing. The absence of high velocities again suggests that the comfort index is being influenced predominantly by temperature.

v) PPD less than 10.

As the PPD value is derived from the PMV, the profile, Figure 6.31 also shows values outside acceptable limits with 12.7% of occupants predicted to be uncomfortably cool at feet level.

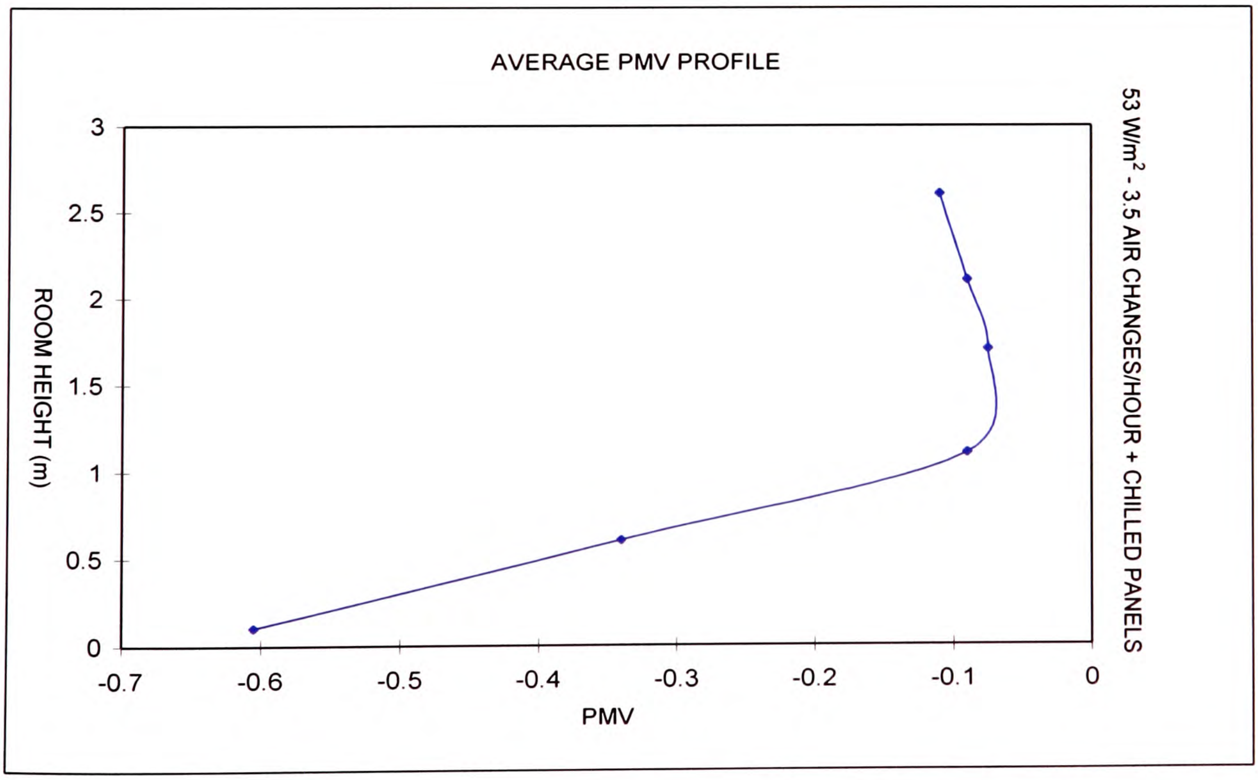


Figure 6.30 Experiment 4 – Average PMV profile

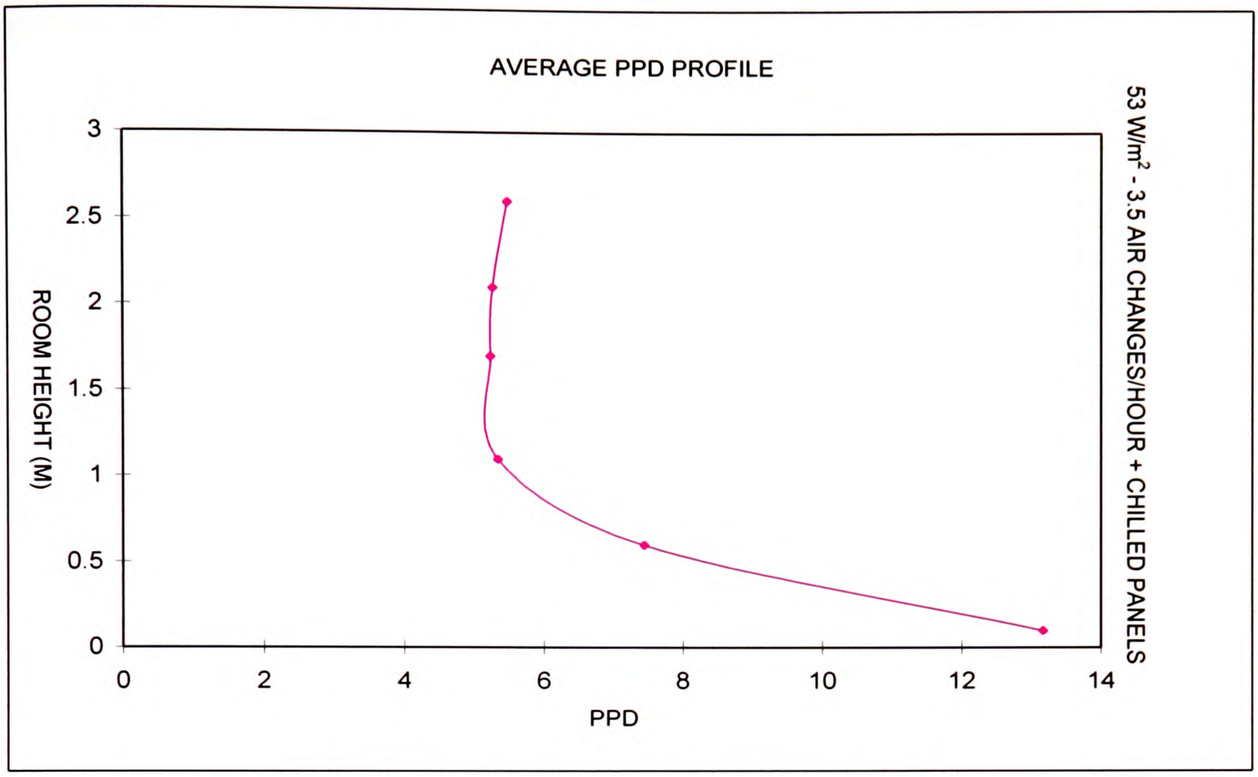


Figure 6.31 Experiment 4 – Average PPD profile

6.7 Comparisons between Experiment 3 and Experiment 4

Although the results for Experiment 3 did not indicate that the theoretically ideal comfort conditions were met, they were in fact very similar to those for Experiment 4.

As identified in section 5.7.1, using the same measurement grid for the textile diffuser places it at a slight disadvantage for comparison with the conventional systems. With the textile diffusers distributed along two walls of the room, the measuring probe locations at a height of 0.1 m in the first and last rows are actually pressed into the profile of the diffuser. This is measuring conditions that would not be experienced by the occupants of the room, and is therefore giving a false comparison. For this reason, and for this critical comparison, a revised data set was created that excludes the 18 measuring points at a height of 0.1 m along the two diffuser walls. The effects of this revision are shown on the set of result graphs prefixed 'revised', Figures 6.32 – 6.35. The revised results are used for direct comparison with the results of Experiment 4.

6.7.1 Comparison of temperature results

From the revised data, the average temperature at 0.1m becomes 20.6 ^{o}C (instead of 20.4 ^{o}C) with a minimum temperature of 19.3 ^{o}C (instead of 18.3 ^{o}C).

The comparison between the two systems provides some interesting findings (see Figure 6.32). Firstly, both systems successfully limit the temperature in the occupied zone to less than 26 ^{o}C. Secondly, the temperature at floor level is similar, 20.6 ^{o}C for experiment 3 and 20.9 ^{o}C for experiment 4. Finally both systems effectively limit the gradient to less than 3 K/m. In respect of thermal comfort conditions, both systems satisfy the criteria. However, the chilled panel system, (experiment 4) is more effective in limiting the temperature rise and is therefore, more comfortably within limits.

This direct comparison of temperature profiles provides other information on system performance, in addition to thermal performance. Both temperature profiles show an abrupt change of gradient (see Figure 6.32). The point at which the gradient becomes vertical indicates where displacement flow breaks down and a mixing regime occurs. This point is critical, as the primary reason for using displacement ventilation is to provide better air quality than is possible when using a mixing system. It is appropriate to state here that a primary objective of this thesis is to identify a method of increasing displacement ventilation flow rates to maintain thermal comfort conditions in the occupied space whilst still maintaining air quality levels.

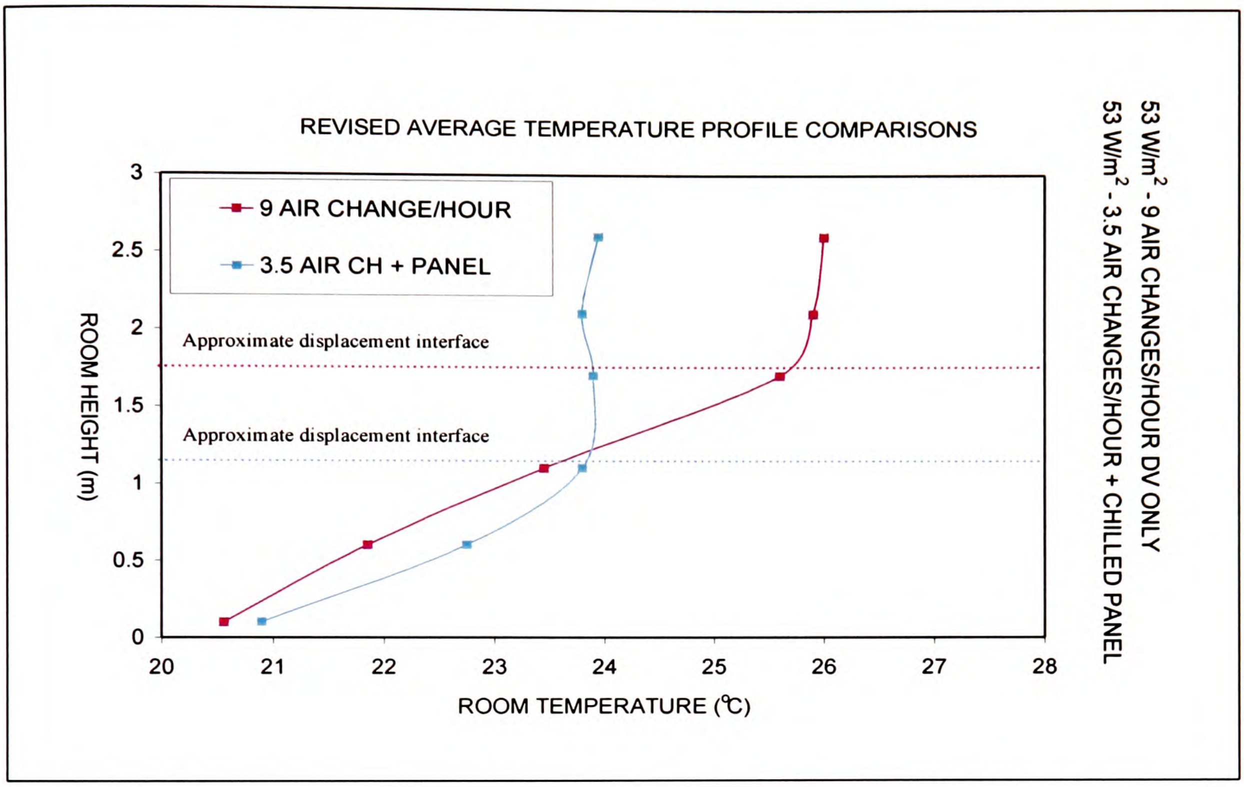


Figure 6.32 Average temperature profile comparisons (Experiments 3 and 4)

The results for the chilled panel system indicate that the transition from displacement flow to mixed flow occurs at approximately 1.1 m above the floor, so that for a person seated in the room, their breathing zone will be in the mixed region. For the textile diffuser system, this transition occurs at approximately 1.75 m above the floor, so that a person sitting or standing, is experiencing unmixed air in their breathing zone.

6.7.2 Comparison of velocity results

With the revised data the maximum velocity at 0.1 m is 0.14 m/s (instead of 0.2 m/s).

From the temperature profiles, it has been deduced that superior air quality is achieved using the textile diffusers, whilst temperature criteria are still met. The concerns identified in the literature review are that increasing air flow rates to achieve good air quality or extra cooling will result in draughts at low level. Figure 6.33 shows that average velocities do not exceed 0.1 m/s, which is well within comfort criteria.

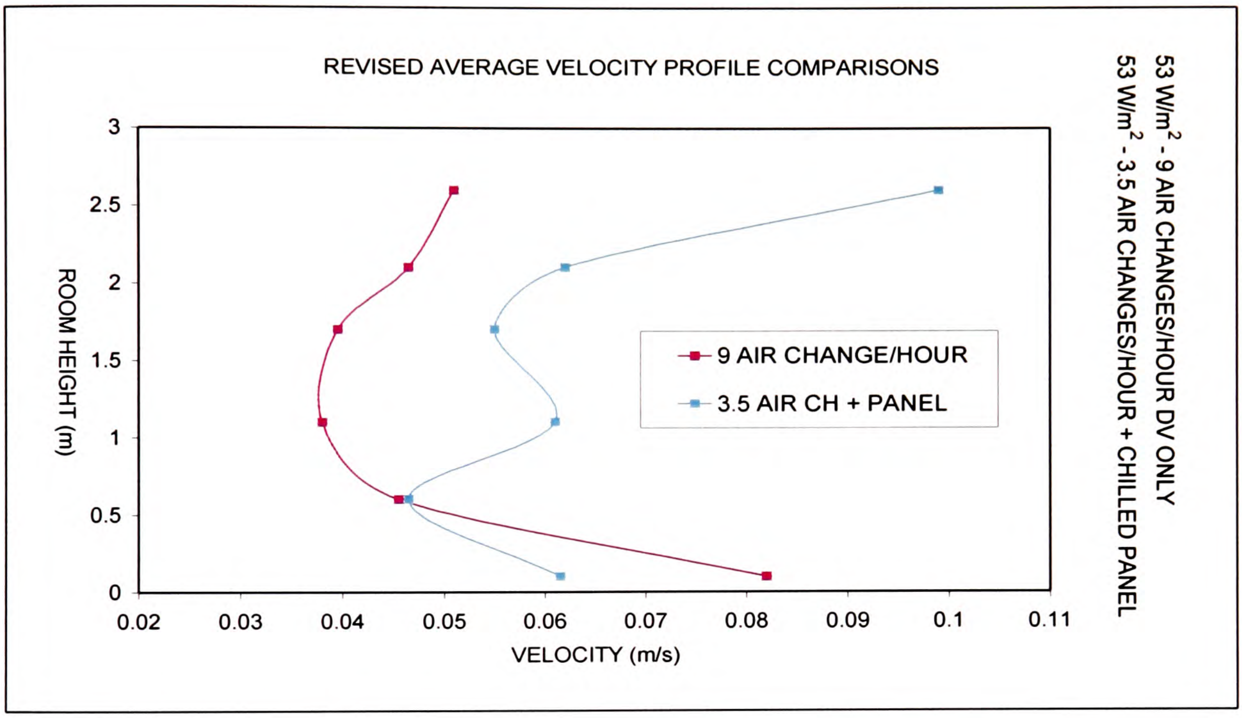


Figure 6.33 Average velocity profile comparisons (Experiments 3 and 4)

6.7.3 Comparison of PMV and PPD results

When the revised data are considered, the feet level PMV rises to –0.56 (from –0.6). and the feet level PPD falls slightly to predict that 12.2% of occupants will be slightly cool (from 12.4%). These comfort indicators are inter-related. As shown by Figure 6.34 both systems exceed the comfort criteria at the slightly cool end of the scale, by a similar amount, showing that the textile diffuser is at least no worse than the chilled panel system in this respect. When these results are translated to PPD, the textile diffusers produce a figure of 12.4% and the chilled panels, 12.7% as shown in Figure

6.35. Although higher than the ideal of 10%, anything up to 20% is acceptable for most building applications.

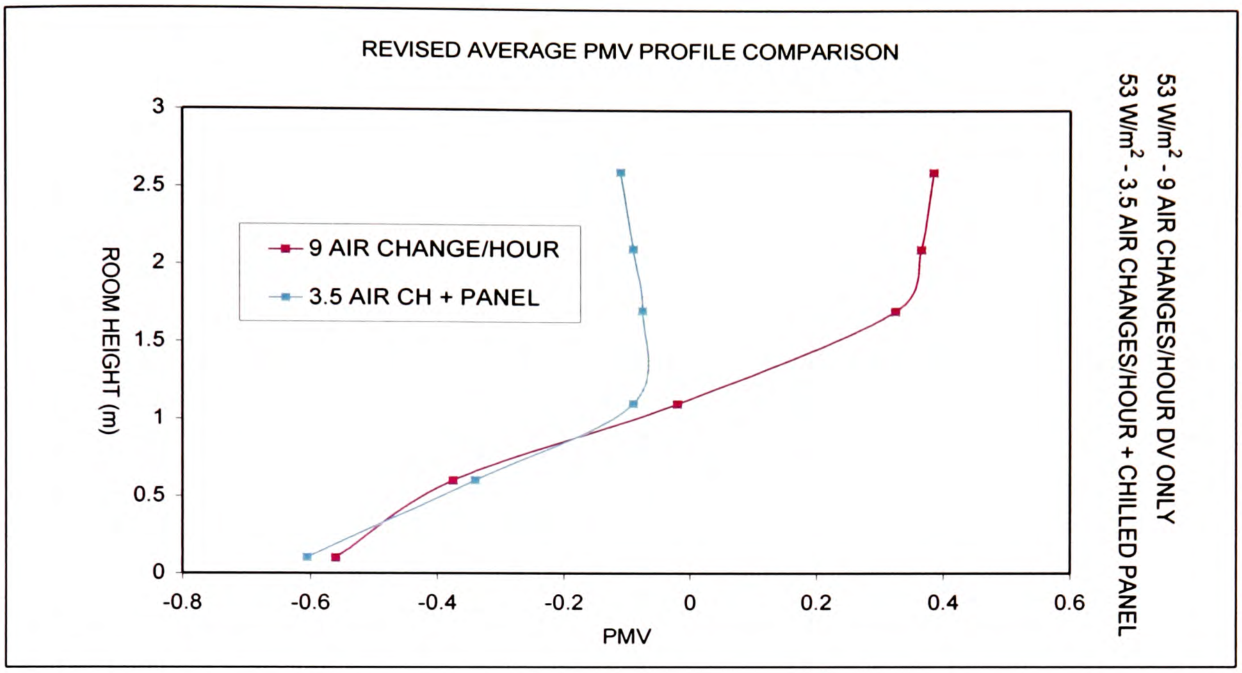


Figure 6.34 Average PMV profile comparisons (Experiments 3 and 4)

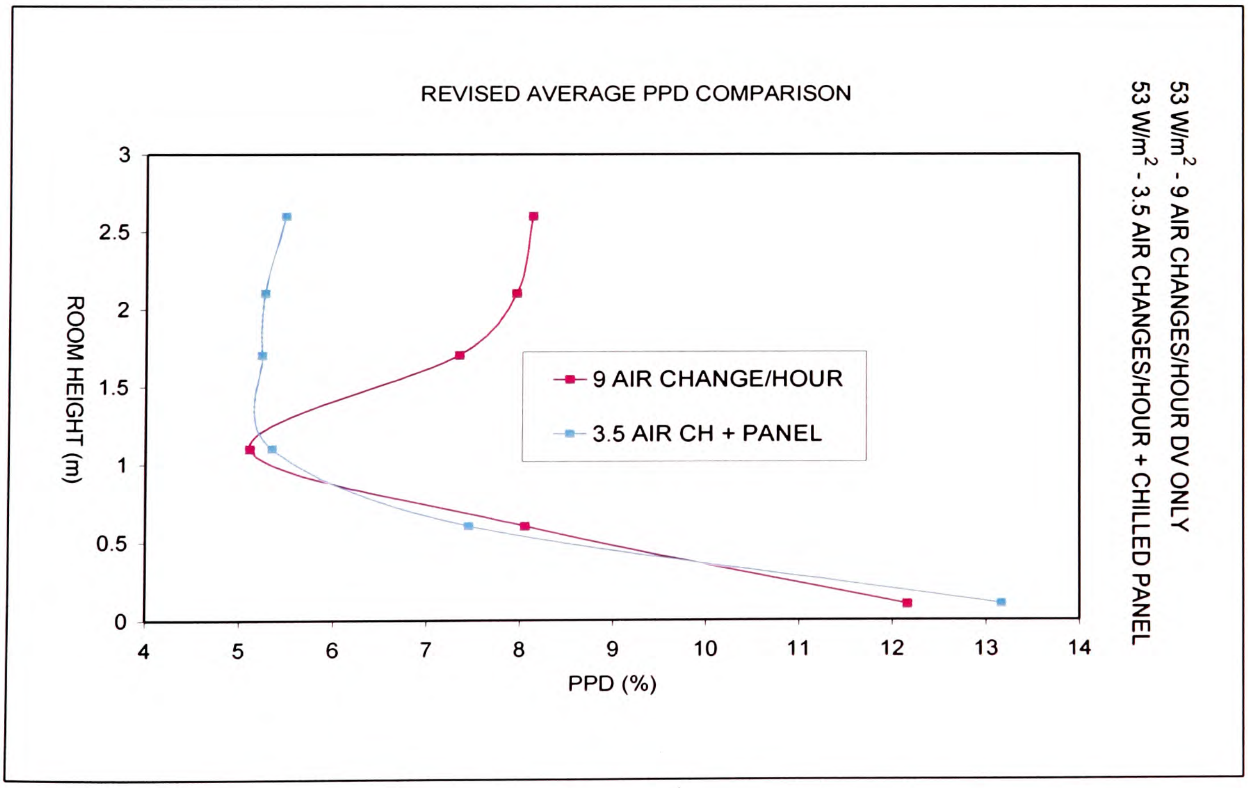


Figure 6.35 Average PPD profile comparisons (Experiments 3 and 4)

6.8 Summary of principal findings

This programme of experimental work has produced the following principal findings:

i) The use of a textile diffuser for displacement ventilation allows for relatively high volume flow rates, (when compared with other types of diffuser), without causing uncomfortable draughts (see Figure 6.33).

ii) The use of a higher volume flow rate results in the maintenance of the displacement flow regime from floor level to a height of 1.75m. The lower volume flow rate system using supplementary static cooling devices in the ceiling only maintained the displacement flow regime to a height of 1.1m (See Figure 6.32).

iii) Using the ISO 7730 (1992) thermal comfort indices of PMV and PPD the performance of the high volume flow rate textile diffusers was comparable with the standard system with supplementary static cooling devices (See Figures 6.34 and 6.35).

Chapter 7

Case Studies

7.0 CASE STUDIES/CONTEMPORARY RESEARCH

Before embarking on a detailed discussion of the results of this research programme, it is worthwhile to consider other research activity that will be relevant to the discussion. This chapter will review the following:

i) Cost studies that review the whole life costs of various techniques for providing ventilation and air conditioning to commercial buildings.

ii) The results of contemporary research projects that have appraised the technical performance of a variety of methods for incorporating displacement ventilation into the ventilation and air conditioning strategy for a building.

iii) A case study of a displacement ventilation installation that utilises the textile diffuser assessed as part of this research programme.

7.1 Comparative cost studies

Studies comparing the relative costs associated with displacement ventilation based systems and other commonly used air conditioning systems are identified in this section, and an overview of their findings presented.

7.1.1 The Contractor Study (Scott 1994)

Table 7.1 System capital cost comparison (4000m^2 Building)

Air Conditioning System	**Capital cost £/m^2**		
	35 W/m^2	**60 W/m^2**	**90 W/m^2**
4 Pipe Fan Coil	157	168	179
VAV + Reheat	153	173	194
Displacement Ventilation (DV)	134	-	-
Chilled Ceiling + DV + LPHW Heating	-	179	219
Chilled Ceiling + DV + Electric Heating	-	165	205
Chilled Ceiling + Mixing Ventilation	-	152	197

Table 7.2 Maintenance and energy cost comparison

Air Conditioning System	**Maintenance Cost £/m^2**	**Energy Costs at 45 W/m^2**
4 Pipe Fan Coil	2.4	£10575
VAV + Reheat	2.2	£11750
Chilled Ceiling + DV	1.9	£8225

7.1.2 The Consultant Study (Barnard 1996)

Table 7.3 System capital cost comparison (2240 m^2 Building)

Air Conditioning System	**Capital Cost £/m^2**
4 Pipe Fan Coil Units	120
Displacement Ventilation + Convector Heaters	130

Table 7.4 Maintenance and energy cost comparison

Air Conditioning System	**Maintenance Cost £/m^2**	**Primary Energy kWh/m^2**
4 Pipe Fan Coil Units	2.45	210
DV + Convection Heaters	1.17	152

7.1.3 The Cost Consultant Survey (Building Services Journal September 1998)

Table 7.5 Capital cost comparison

Air Conditioning System	**Capital Costs £/m^2 (Cost Model)**
4 Pipe Fan Coil Units	138.60
Displacement Ventilation	83.40
DV + Chilled Ceiling	143.70

7.1.4 Analysis of comparative study

From the Scott study (1994), Table 7.1 provides further confirmation that designers acknowledge the cooling limitations of displacement ventilation alone. The table only has a cost indication for displacement ventilation for a cooling load up to 35 W/m^2, which is at the top end of the range identified in the literature review. For the higher heat loads costs are only provided for displacement ventilation with supplementary cooling. Logically the costs that include supplementary cooling systems are higher than the displacement system alone, but for loads up to 60 W/m^2 they are comparable with the more conventional fan coil and VAV systems. At 90 W/m^2 they are significantly more expensive than the conventional systems. The costs for the displacement ventilation system with a load of 35 W/m^2 are significantly lower than for the conventional systems.

Table 7.2 shows the running cost analysis which has only been carried out for the mid-range cooling load considered, i.e. 45 W/m^2 and so does not include figures for displacement ventilation without static cooling. With less moving parts the maintenance costs for the DV with chilled ceiling systems are the lowest. It is reasonable to expect the DV only system to have even lower maintenance costs. The running costs are also significantly lower for the DV + chilled beam system. The DV only system would be even lower for reasons that will be discussed in Chapter 8.

From the Barnard study (1996), Table 7.3 shows that with the cost of a heating system included, the DV system has a higher cost, although this is misleading as all-air air conditioning systems usually require the addition of a perimeter heating system to offset fabric losses. Table 7.4 confirms that the running costs for the DV system are lower than for the fan coil system.

From the Building Services Journal Study (1998), Table 7.5 shows that the DV system alone has a lower cost than the fan coil system.

7.2 Factors influencing energy consumption of systems.

A detailed energy study is beyond the scope of this thesis and should form the basis of further work. However, as lower energy costs are indicated in the literature, a discussion of the factors that would lead to this conclusion is offered. The discussion will consider two options, firstly the advantages of displacement ventilation with chilled ceilings when compared with fan coil units as identified in 7.1 above, and secondly the further advantages of using displacement ventilation without chilled ceilings.

The comparison is made with fan coil units, as they are the most likely system to be used if a displacement ventilation system is not used. (Building Services Journal 1998).

The significant factors would seem to be the ability to take advantage of free cooling and the Coefficient of Performance (COP) of the associated refrigeration plant.

7.2.1 Free Cooling

Free cooling is the ability to use air at ambient external temperature or enthalpy to provide a cooling effect within a building.

Fan coil units work on the principle of supplying the minimum amount of air to simply satisfy fresh air requirements of the occupants. This air is used to provide a cooling effect as well. The ventilation principle adopted is dilution, so the air is introduced outside the occupied zone where mixing with room air occurs before it enters the occupied zone. To maximise the cooling effect, the lowest supply air temperatures possible are utilised; this is usually 13 – 14 ^{o}C. The balance of any cooling load is provided by chilled water circulated to the cooling coil at a temperature below 13 ^{o}C.

The opportunity for free cooling via the fresh air supply therefore only occurs when the external ambient temperature is less than 13 – 14 ^{o}C. The proportion of cooling load that is provided by the fresh air supply is usually no more than 20%, to keep the duct size small. The balance of the cooling load does not readily lend itself to taking advantage of free cooling, and this is not usually achieved.

In summary, a fan coil system is only able to provide up to 20% of the cooling load as free cooling and only for the period of time when the external air temperature is less than 13 – 14 ^{o}C.

As has been identified in the literature review, displacement ventilation in combination with a chilled ceiling system is only required where cooling loads are in excess of 20 – 30 W/m^2. To discuss energy consumption in principle, a cooling load of 50 W/m^2 will be taken as typical. This would mean that the cooling load was shared equally between the ventilation system and the chilled ceiling. In practice this figure is low, and represents the summation of best practice heat gains excluding solar gains (CIBSE GUIDE 1998). Few existing buildings will have peak cooling loads as low as this but peak loads only occur for brief periods. Additionally, current design trends are to use the fabric to better effect in reducing solar heat gains passively and in time loads of 50 W/m^2 will become more typical. Proposals to limit the energy impact of air conditioning systems through the Building Regulations at the next revision to Approved Document L will further this trend (King 1999).

Displacement ventilation works on the principle of introducing the supply air into the occupied space at a temperature 1-2 K lower than the room air temperature. This results in a typical supply air temperature of 19 ^{o}C.

The opportunity for free cooling via the fresh air supply therefore occurs when the external ambient temperature is less than 19 ^{o}C. The balance of the cooling load is provided by circulating chilled water through the ceiling elements at no less than 14 ^{o}C (Martin 1997). Again, the balance of the cooling load does not readily lend itself to taking advantage of free cooling, and this is not usually achieved.

In summary, a displacement ventilation system supplemented with a chilled ceiling is typically only able to provide 50% of the cooling load as free cooling and only for the period of time when the external air temperature is less than 19 ^{o}C.

The experimental results using textile diffusers indicate that loads of up 50 W/m^2 can be dealt with by displacement ventilation alone, without the need for supplementary cooling devices. This results in the ability to take advantage of free cooling for the entire load for the period of time when the outside temperature is less than 19 ^{o}C.

A summary of the free cooling factors discussed is shown in Table 7.6

Table 7.6 Free cooling factors

Air conditioning system	% of load by free cooling	Free cooling period
Fan coil units	Up to 20%	External temperature < 14°C
Displacement ventilation + Chilled ceiling	Up to 50%	External temperature < 19°C
Displacement Ventilation with textile diffusers	100%	External temperature < 19°C

Weather data has been analysed to demonstrate the scale of free cooling available (Butler 1998). The work by Butler (1998), provides a useful indication of the scale of free cooling available by increasing the range of displacement only systems as proposed by the author. Butler (1998) proposes that compared to conventional systems such as fan coil systems, the higher chilled water temperatures associated with the use of ceiling mounted static cooling devices provide ample scope for free cooling benefits. Further to this, Butler proposes that the free cooling may be optimised by the use of evaporative cooling. This technique allows the cooled medium to approach the ambient wet bulb temperature which would normally be lower than the dry bulb temperature, and would be significantly lower during the daytime in summer when the ambient relative humidity is low. This coincides well with periods of peak cooling demand.

In pursuit of optimising the benefits of free cooling, Butler, (1998), has also investigated the thermal comfort implications of raising the chilled water temperature to 18 °C. This coincides with the temperature required to cool the supply air for displacement ventilation.

A summary of the analysis of historical meteorological data carried out by Butler, (1998), is shown below.

Table 7.7 Percentage of the cooling period April to September 0700 to 1800 that evaporative cooling alone is viable.

Chilled water temperature	Percentage of year 1976-80	1976 (A hot year)	1977 (A cool year)
15.5 °C or below	38%	32%	43%
18.5 °C or below	70%	59%	78%

Table 7.8 Percentage of the cooling period June to August 0700 to 1800 that evaporative cooling alone is viable.

Chilled water temperature	Percentage of year 1976-80	1976 (A hot year)	1977 (A cool year)
15.5 °C or below	15%	7%	20%
18.5 °C or below	54%	33%	67%

This data illustrates the scale of the potential for free cooling. When the whole season is considered, the ability to utilise chilled water at 18.5 °C instead of 15.5 °C, increases the period that free cooling is available from 38% of the time to 70% of the time. During the peak months this change is from 15% to 54%. Whether utilised as chilled ceilings or displacement ventilation, this data promises significant energy benefits over systems that are unable to utilise this free cooling.

7.2.2 Coefficient of Performance (COP)

The term Coefficient of Performance) is the term used by refrigeration engineers to describe the efficiency of a refrigeration machine. It is usually defined as the ratio of the refrigerating effect produced (W), to the net work supplied (W). This is generally expressed in the form:

$$\mathrm{COP} = \frac{\text{heat energy absorbed}}{\text{heat energy equivalent of net work sup plied}}$$

From the theoretical Carnot Cycle it can be shown that the COP can be expressed as:

$$\text{Theoretical COP} = \frac{T_e}{(T_c - T_e)} \qquad \text{where,}$$

T_c is the Absolute Temperature of Condensation (K), usually dictated by outdoor ambient temperature.

T_e is the Absolute Temperature of Evaporation (K), the required temperature of refrigeration.

It can be seen from this relationship that the smaller the difference between T_c and T_e, the higher the COP, or the higher the efficiency. As the external ambient temperature fixes the condenser temperature, the relative energy performance of the cooling options being compared is a function of evaporator temperature. The lower the temperature required, the lower the thermal efficiency. Table 7.9 gives an indication of the relative chilled water temperatures for the options under consideration.

Table 7.9 Chilled water temperatures

Air conditioning system	Temperature °C
Fan coil units (Tozer et al 1997)	6 °C
Displacement ventilation + Chilled ceiling (Martin 1997)	14 °C – 18 °C
Displacement Ventilation with textile diffusers	14 °C – 18 °C

In conclusion, this combination of higher percentage of free cooling opportunity, and higher evaporator temperatures results in lower energy costs in situations where the entire cooling load can be met with the use of displacement ventilation alone.

7.3 Ongoing Chilled Ceiling Research

This research activity and associated commercial uptake could arguably be running counter to current design philosophy in two major respects in addition to the air quality concerns (Geens 1997). The positioning of static cooling at ceiling height introduces a false or lowered ceiling with the following consequences:

- the creation of a barrier to building fabric thermal storage by the ceiling slab.

- the depression of the high temperature zone towards the occupied zone, when lower loads are not requiring the ceiling panel input, and displacement ventilation is being achieved.

If the ceiling slab itself could be used as the chilled surface, these problems would be overcome. The incorporation of a chilled water circuit within the ceiling slab has been investigated (Arnold 1999).

At the outset of this project, the aim was to provide knowledge that would allow a wider uptake of displacement ventilation. It is interesting to note that a recent BSRIA report on European markets for chilled ceilings and displacement ventilation (BSRIA 14 400/5 1999), identified that although there had been a growth, in the market, these systems only accounted for 2% of the UK market. This growth since 1994 had resulted in a reduction in the average price, for example for chilled ceilings, from £105/m^2 to £70/m^2. The report also identified that the market is dominated by split systems with 58% of the market. As reported in the Building Services Journal (October 1999) BSRIA's survey discovered a reluctance by many consultants to specify chilled panel or chilled beams due to their lack of knowledge. The BSRIA Code of Practice (BSRIA COP 17/99) project of which this thesis forms a constituent part is intended to overcome this lack of knowledge.

With the reluctance to specify being related to lack of knowledge, it is appropriate to this discussion to analyse the findings of recent research aimed at overcoming this lack of knowledge. Within the UK this will include the work of Arnold (1999), Butler (1997), Martin (1997), and Wyatt (1999) along with that of the author.

Butler and Martin have both been working on the principle that displacement ventilation only systems are limited in application to cooling loads of no more than 20W/m^2, and have therefore concentrated on some of the problems associated with the use of supplementary cooling using chilled ceilings.

7.4 Condensation control for chilled ceilings and beams (Martin 1997)

The work carried out by Martin was based on physical modelling using the modified test facility developed by the author. Martin, (as identified in 3.4), concludes that it is possible to "design out" condensation risk, but that there is an energy penalty associated with the necessary supply air dehumidification or a loss of cooling performance if chilled water temperature control is used. The energy penalty whilst not desirable would be no worse than for the split systems identified in the BSRIA market report (1999), as one of the primary alternatives being specified, or fan coils that make up a large proportion of the centralised systems being specified (Building Services Journal 1998). However Martin does identify a number of constraints on the success of these strategies as follows.

i). The selection of suitable temperature differentials to maintain the room dewpoint away from the chilled water temperature in order to avoid condensation should take into account the following:

- sensor drift (a 5% RH variation equates to $1^{\circ}C$ dewpoint variation)
- sensor calibration
- localised latent heat gains remote from the point of measurement, for example gains due to air infiltration, plants, wet coats, or hot drinks
- localised sensible heat gains, for example above a photocopier
- inaccuracies in the calculation of the dew point algorithm
- a sufficient time allowance for the control system to react to a change in load.

To achieve this in practice a differential of 2 K between the room dewpoint and the chilled water temperature is suggested as being realistic to avoid the formation of condensation, but this assumes conscientious maintenance and a suitable awareness of building sensible and latent heat gains.

ii). The purchase of a good quality RH sensor and subsequent regular calibration is particularly important to the success of the control strategy.

iii). The use of condensation detectors as control devices may be appropriate in some low cost installations. However, the tests indicated a rapid loss of comfort due to the disabling of the chilled water supply. There is also a danger that failure of a detector may lead to water damage.

iv). Temperature and RH sensors used to determine room dewpoint should be positioned away from sensible and latent heat sources and, particularly away from cool downdraughts created by the chilled ceilings. Ideally temperature sensors should be accurate to $\pm$ 0.2 ^{o}C and relative humidity sensors to $\pm$ 3%.

7.5 Chilled ceilings and beams – BRE research (Butler 1997)

The work carried out by Butler was complementary to the work of Martin in studying the condensation risk in four occupied buildings. This study highlighted a number of minor problems, summarised here.

7.5.1 Building 1 – An open plan office with a chilled beam system.

The building was operated on a mixed mode basis with an emphasis on minimising chilled beam operation by opening windows on cool days, and allowing temperatures to drift upwards in the afternoon. The intended chilled beam control strategy is to dehumidify the fresh air supply to limit the building internal dewpoint temperature to 13 ^{o}C, and to maintain a minimum 1 K difference between the chilled water entering temperature and the room dewpoint temperature. The room dewpoint is calculated by the BMS from inputs from RH and dry bulb temperature sensors.

Datalogging showed that chilled water temperature control maintained a 2 K differential, tracking minor variations in dewpoint temperature quite accurately. However it was discovered that the reference data provided by the BMS was incorrect. The measured relative humidity of the supply air at the diffuser ranged between 60 and 70% whilst the BMS indicated a value of 40%. This was subsequently traced to a faulty sensor in the air handling unit. Despite this problem, the formation of condensation was not observed.

7.5.2 Building 2 – An open plan office with a chilled beam system.

This building used a condensation control strategy similar to Building 1. However, the monitored data showed that the strategy failed to operate, with room dew point temperature exceeding the chilled water entering temperature by up to 1 K on several occasions. Although this created a theoretical risk of condensation, none of the occupants reported noticing any condensation.

7.5.3 Building 3 – An open plan office with a chilled panel system.

The condensation control strategy in this building is to switch off chilled ceiling panels if the zone RH rises above 65%, and reset when the RH falls below 55%. The monitored data showed that room RH never exceeded 65%. The room design set point temperature was 22 °C, which at an RH of 65% gives a dewpoint temperature of 15 °C. With a chilled water design temperature of 14 °C this indicates a condensation risk as the water temperature is below the dewpoint temperature. On some of the warmer days, the chilled water supply temperature dropped to 11 °C, thereby increasing the risk. Despite this the occupants reported no condensation, confirming that in practice the surface temperature of the panels is 1 or 2 K higher than the temperature of the entering chilled water. That theory is not far removed from practice was confirmed during the period following commissioning, when a control fault resulted in a chilled water supply temperature as low as 6 °C. The heavy surface misting that this caused was sufficient to alert the building operator to the problem, which was rectified before falling droplets developed.

7.5.4 Building 4 – An intermittently occupied company board room with a demonstration chilled ceiling 'pod' suspended from the existing ceiling.

The condensation control strategy is similar to Buildings 1 and 2 in that a minimum 2 K differential is maintained between the chilled water inlet temperature and the calculated room dew point temperature. However with this system a condensation detector was also fitted to switch off the chilled water flow in case the control strategy failed. This detector was unlikely to operate as it was found to be connected to the (warmer) return pipe instead of the flow pipe, and was also in loose contact.

7.5.5 The measurement of coldest surface temperatures.

Butler (1998) makes the following observations on surface temperatures.

Most of the condensation control strategies assume that the chilled ceiling or beam temperatures are the same as the chilled water inlet temperature in determining the risk of condensation. This assumption is incorrect as there is a temperature gradient from the water, through the waterside surface film resistance and metal to the metal surface that will result in an unnecessary safety margin that could limit cooling output on hot days. Results from the testing at BSRIA (Martin 1997), for example, suggest that chilled panel surface temperatures are generally around 2 ^{o}C higher than the chilled water inlet temperature. For chilled beams a much lower temperature difference would be expected due to the more effective heat transfer between the metal fins and the chilled water pipes.

This means that the strategy used in Building 4 will result in a difference of 4 K between surface temperature and chilled water inlet temperature, which is an unnecessarily high safety margin. Buildings 1 and 2 having chilled beams would have smaller margins, but still larger than necessary.

7.6 Discussion of condensation risk work.

From the field trials, Butler (1998) concludes that it has been demonstrated that chilled panels and beams have been effective in the buildings investigated, but that it is not clear whether there is a sufficiently high risk of condensation to justify the general use of avoidance control strategies. He suggests that designers and manufacturers are specifying such controls just to be safe, but makes a case for simple designs as the study identified several faulty systems, which caused, rather than solved problems. Butler and Martin both indicated that further studies would be required to investigate unusual transient conditions, such as the use of office kettles or where staff arrive in the office with wet clothes when it is raining. In apparent contradiction of these conclusions Butler (1997) does include the following statement in his research "....BRE's early view that condensation could still form on the chilled water inlet pipework was confirmed by testing. Whether this moisture forms and re-evaporates unnoticed during normal operation or may lead to more prolonged wetting of the "unseen" surfaces, is not yet resolved".

Although laboratory and field trials indicate that an appropriate control strategy results in a low risk of surface condensation and droplet formation, these findings only re-enforce the viability of a design principle that in the case of supply air de-humidification is already widely applied to the design of fan-coil units which Butler (1997) acknowledges are similar in principle to chilled beams.

It is worth noting that many of the constraints on the success of these control strategies identified by Martin (1997) and reported in 7.4.1 above were demonstrated as the causes of some of the problems subsequently discovered during the field trials. The limited nature of the field trials and the number of minor installation or commissioning problems identified will do little to overcome the reluctance of designers to specify these systems.

It is the view of the author that the perceived condensation problem with chilled ceilings is misconceived, although in 1995 the CIBSE President's prize for best student paper went to a student from Loughborough with a paper investigating the possibility of using condensation from chilled beams to water office plants! More significant concerns are the introduction of water pipes into the ceiling void of modern electronic offices. Every joint in the system is a potential leak, which at the time of the leak will result in more water damage than condensation drips. One of the problems identified in the field trials, in Building 4 is a good example of this. The chilled ceiling panels used were connected to the supply and return pipes with push fit flexible pipes. When a chilled ceiling panel had to be swung down for access to the ceiling void during the monitoring period, a push fit connection was found to be leaking, causing water to accumulate above the panel and soak the insulation material. It may be appropriate to use leak detection tape throughout the installation, which would give warning of both condensation formation, and water leakage.

The aim of this research is to encourage the use of systems that provide an alternative to fan coil systems, i.e. that provide better air quality, use less energy, and cause less maintenance problems whilst maintaining thermal comfort. The video capture evidence presented in Chapter 4 demonstrates that the use of chilled ceilings with displacement ventilation, results in re-circulation of exhausted air, thus negating any potential air quality benefits. From the evidence presented by Martin and Butler, the systems do provide thermal comfort, but necessitate the use of energy intensive dehumidification to avoid condensation risk, and re-introduce many of the maintenance problems associated with fan coil units. Whilst this may satisfy designers in some situations, other strategies need to be considered.

7.7 Using the building mass as the chilled ceiling

The problems of lost passive cooling associated with obscuring the thermal mass of the ceiling with chilled panels as identified in 7.5 above, have been addressed by work carried out by Arnold (1999). This work investigates the benefits, not only of exposing the ceiling slab to allow passive cooling, but of incorporating embedded pipes to create a chilled ceiling with free cooling potential.

7.7.1 The chilled slab concept.

The concept of the chilled slab combines the energy efficient techniques of:

a) free cooling and thermal storage, taking advantage of lower ambient temperatures overnight, and

b) cool radiant effect of chilled ceilings

Water is cooled overnight, by circulation through a dry cooler. The water in turn, cools the core of the slab overnight and acts as a low temperature thermal store. The stored "coolth" is utilised gradually during the course of the following day and cools the space by radiation and convection. The slabs are constructed from continuous circuits of plastic pipes buried in cast in-situ floor slabs. The ends of each plastic pipe circuit are extended outside and beneath the slab and connected to cooling water system pipes at high level. The cooling performance of the slabs, with pipes buried to a depth of 70 mm above the soffit, was found to be 27 W/m^2 using water, cooled overnight to 19 ^{o}C.

Arnold (1999) compares the performance of this technique with the more conventional technique of optimising the passive cooling of an exposed slab by night ventilation. He reports the rate of cooling achievable from the night ventilation technique is 15 W/m^2. The use of chilled water in buried pipes is therefore almost doubling the amount of free cooling that can be captured. This technique also allows the incorporation of mechanically chilled water to boost the cooling capability to 60 W/m^2, if this is required, giving a mixed mode system.

It is interesting to note that Arnold reports difficulties in persuading a client to utilise this technique, despite the fact that the architect was enthusiastic about the possibility of having a completely clean ceiling, free from unsightly services. The client's main concerns were that the technique was new and untried, there was no cost information, the performance was unknown and it did not comply with the conventional view of air conditioning. However, the combination of reputation, resources, and experience, (a similar scheme had been used successfully in Switzerland and Austria), resulted in the client being persuaded.

The author has also experienced this problem of convincing a potential client to be the "guinea pig" in using innovative techniques. A number of building operators have expressed an interest in the air quality benefits that have been demonstrated by the experimental work presented in this thesis. However, discussions have always ended with a request to see the system in use in a building. This could be indicative of the conservative nature of the industry as the idea of a system that had never been used before seemed alien to those spoken to. Equally it could be that the reputation, resources and experience of the author were insufficient to sway the potential user.

Fortunately, an organisation with these attributes recognised the merits of the solution proposed in this thesis for a Conference Centre/Restaurant complex that they had been asked to develop a ventilation design for. This installation which provides validation in use of the physical modelling carried out by the author is described in 7.8.

7.8 Textile Diffusers in use

Due to the collaborative nature of the work at BSRIA, Hoare Lea and Partners have maintained regular communication with the author with respect to this project, and they have provided the technical information in this section with the permission of their client. This data has not been published previously and should be treated as confidential.

The Consulting Engineers Hoare Lea & Partners were commissioned as the Building Services Consultants for a conference centre and restaurant at the European headquarters of a Multi-National company. The brief for the ventilation was unusual, as it required very high fresh air supply rates. The specification was to meet the requirements of the ASHRAE ventilation standard, (ASHRAE 62 – 1989), for buildings where smoking is allowed, of 30 l/s/person using displacement ventilation. This requirement in combination with the density of occupation in the theatre style conference room, resulted in higher air supply rates than the project engineers at Hoare Lea had previously experienced. Their conclusion was that their usual design solutions would not be adequate for this installation, with noise and draught problems anticipated, and it was therefore referred to their Research and Development team.

Aware of the research by the author, (Geens 1997), the research team decided that the use of textile diffusers proposed in Geens' paper presented a possible solution to the problem. To satisfy the requirements for the Conference Centre, air flow rates of twice those verified by Geens (1997) were required. This was not thought to be a problem with respect to draught risk as the research showed that velocities experienced were considerably below comfort thresholds. This indicated scope for further increasing volume flowrates. Noise levels had not been recorded in the earlier research, but subjective observations indicated that noise had been generated at the inlet to the diffuser, (Geens 1997a). The design of the textile diffuser was therefore modified, to have multiple inlets, and subsequent testing at the test facility of Senior Coleman, (1999) confirmed that noise levels were acceptable.

Following extensive computer modelling by Hoare Lea and Partners this system has been installed as a displacement ventilation only system, with no supplementary cooling devices. The general arrangement of the rooms is shown in Figures 7.1 - 7.6. Details of the modified diffusers are shown in Figures 7.7 – 7.12.

Fig 7.1 Textile diffuser in meeting room

Fig 7.2 Column diffuser in canteen area

Figure 7.3 Textile diffusers in meeting room

Fig 7.4 Close up of diffuser showing detail of encasing slats

Figure 7.5 Column diffusers with canteen in use

Fig 7.6 Flat diffusers with canteen in use

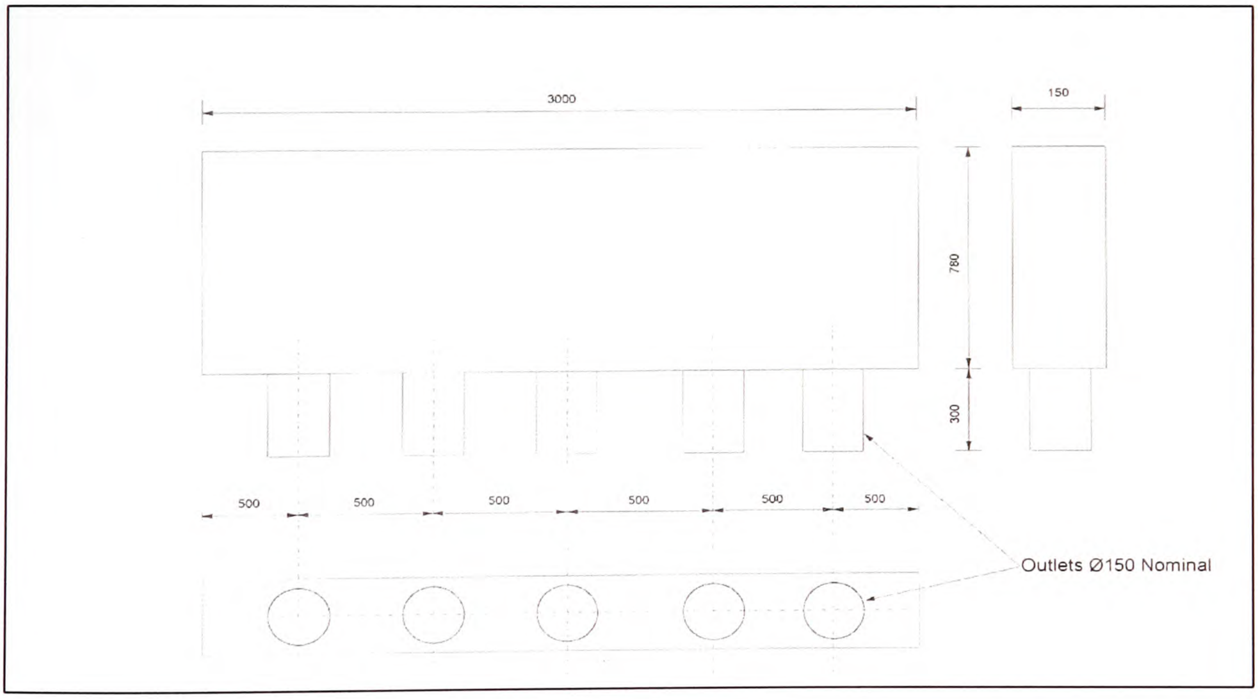


Fig 7.7 Dimensions of wall mounted diffusers

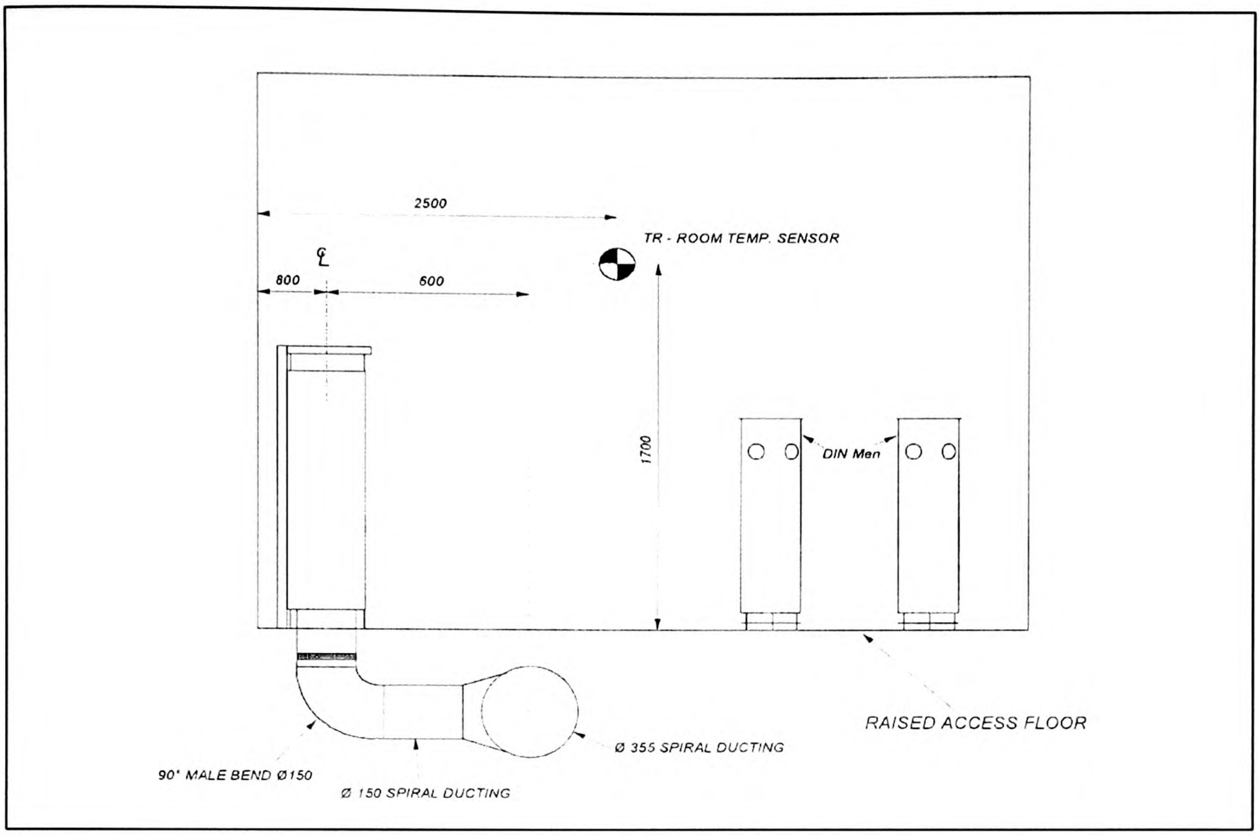


Fig 7.8 Connection details for wall mounted diffusers

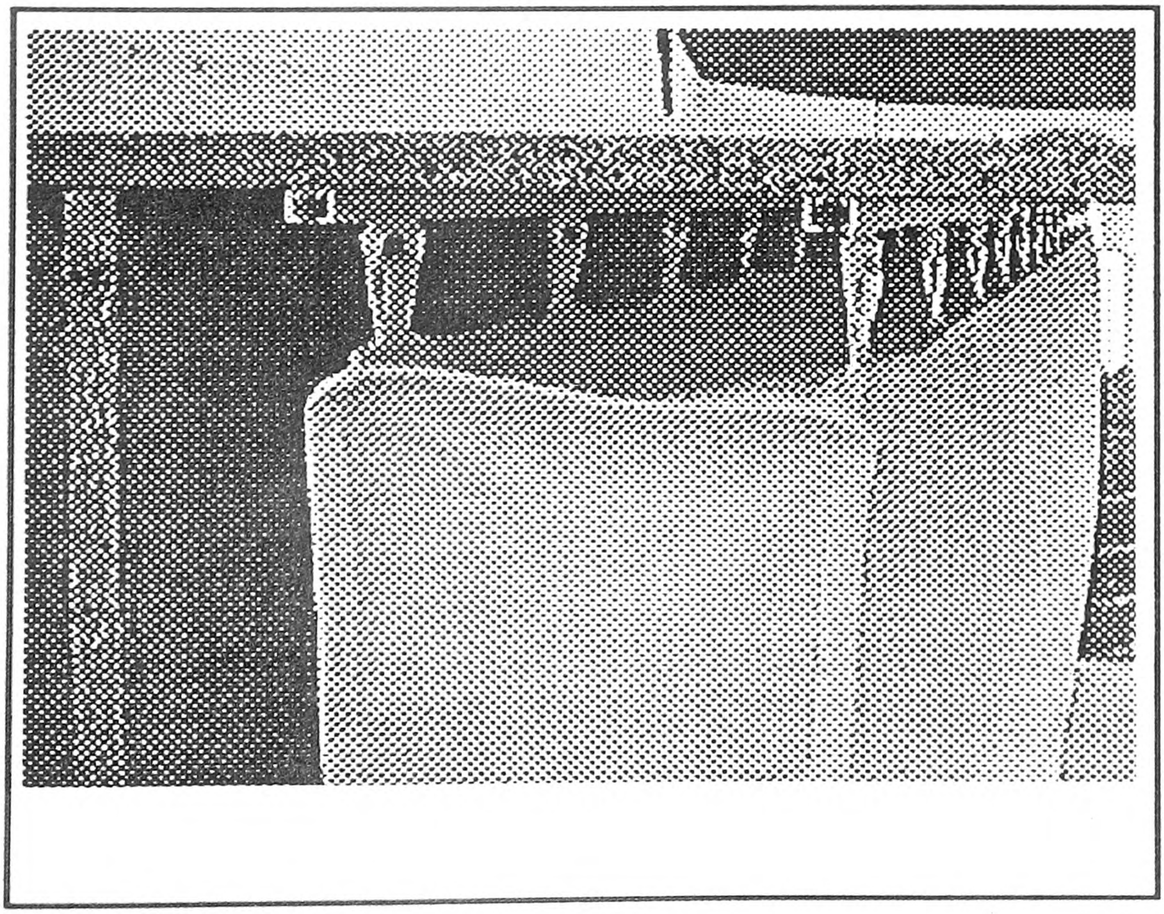


Fig 7.9 Detail of diffuser fixing

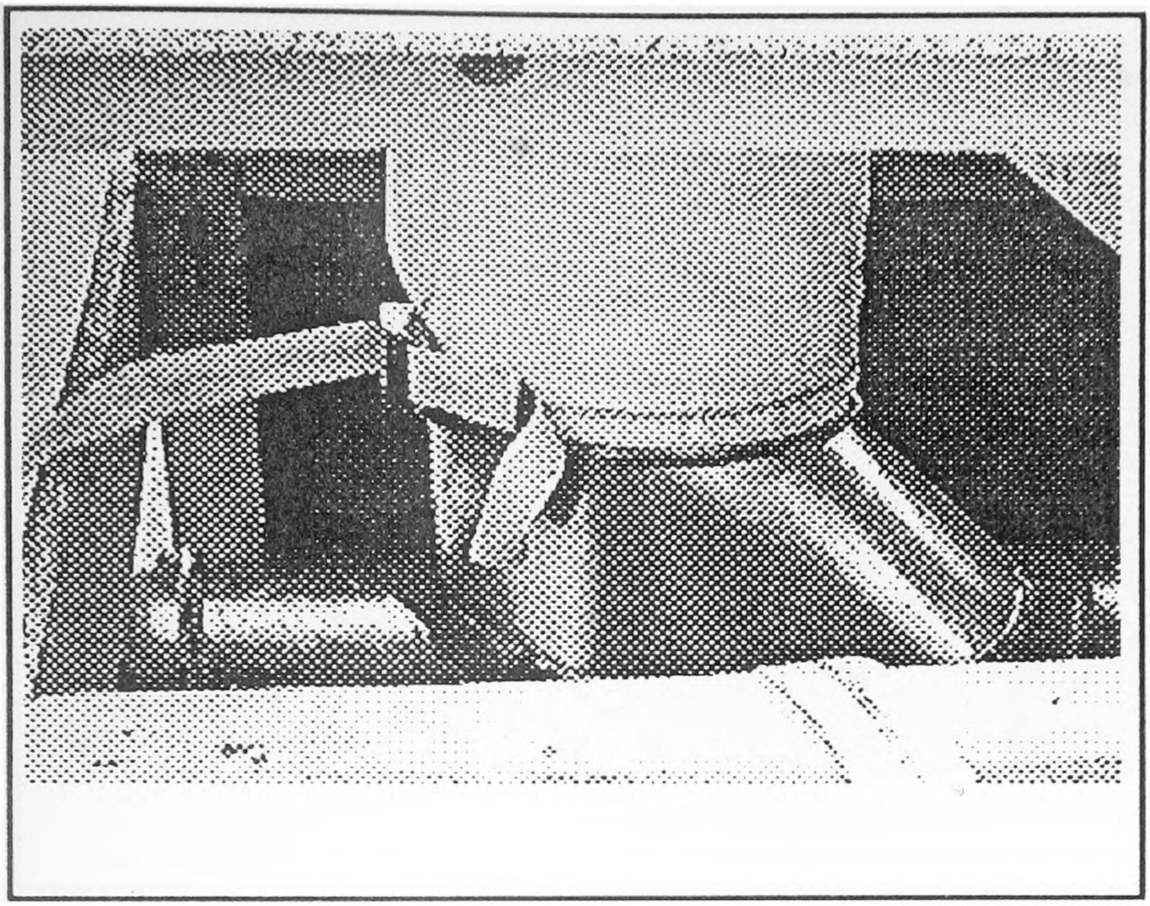


Fig 7.10 Connection detail

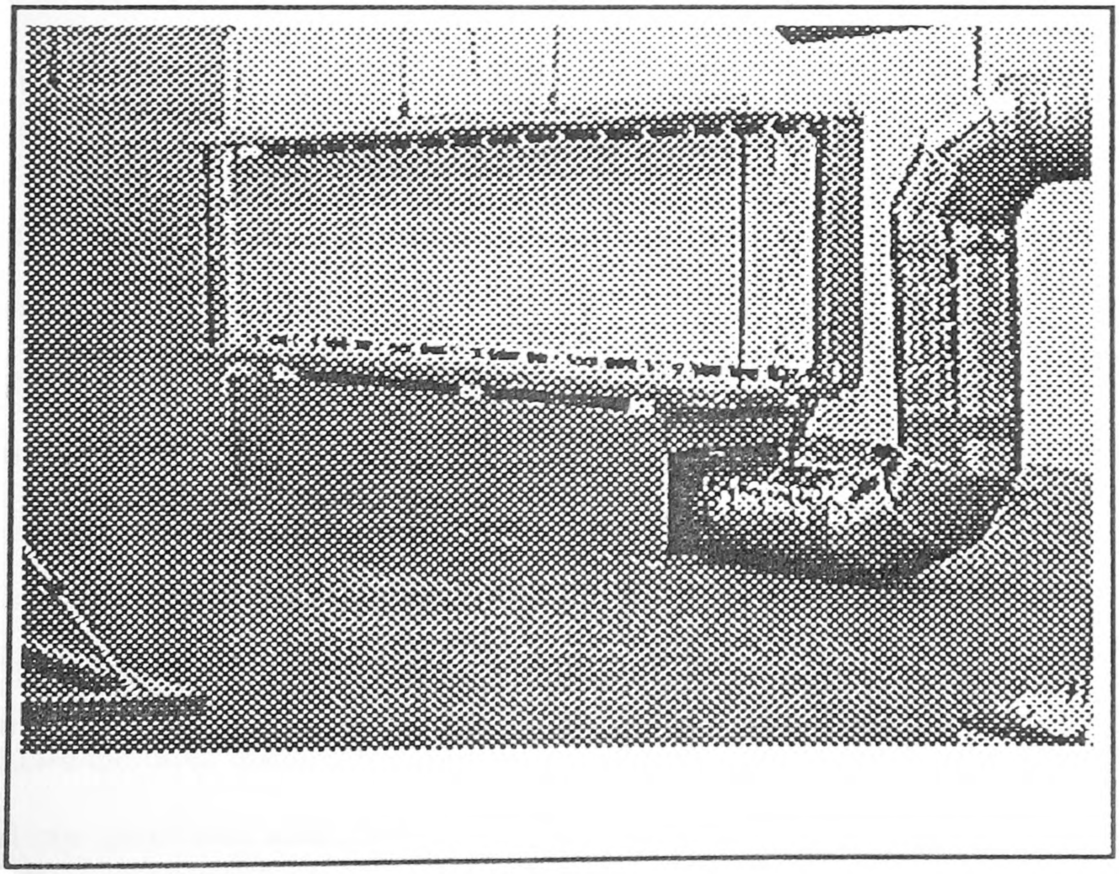


Figure 7.11 Diffuser noise test assembly

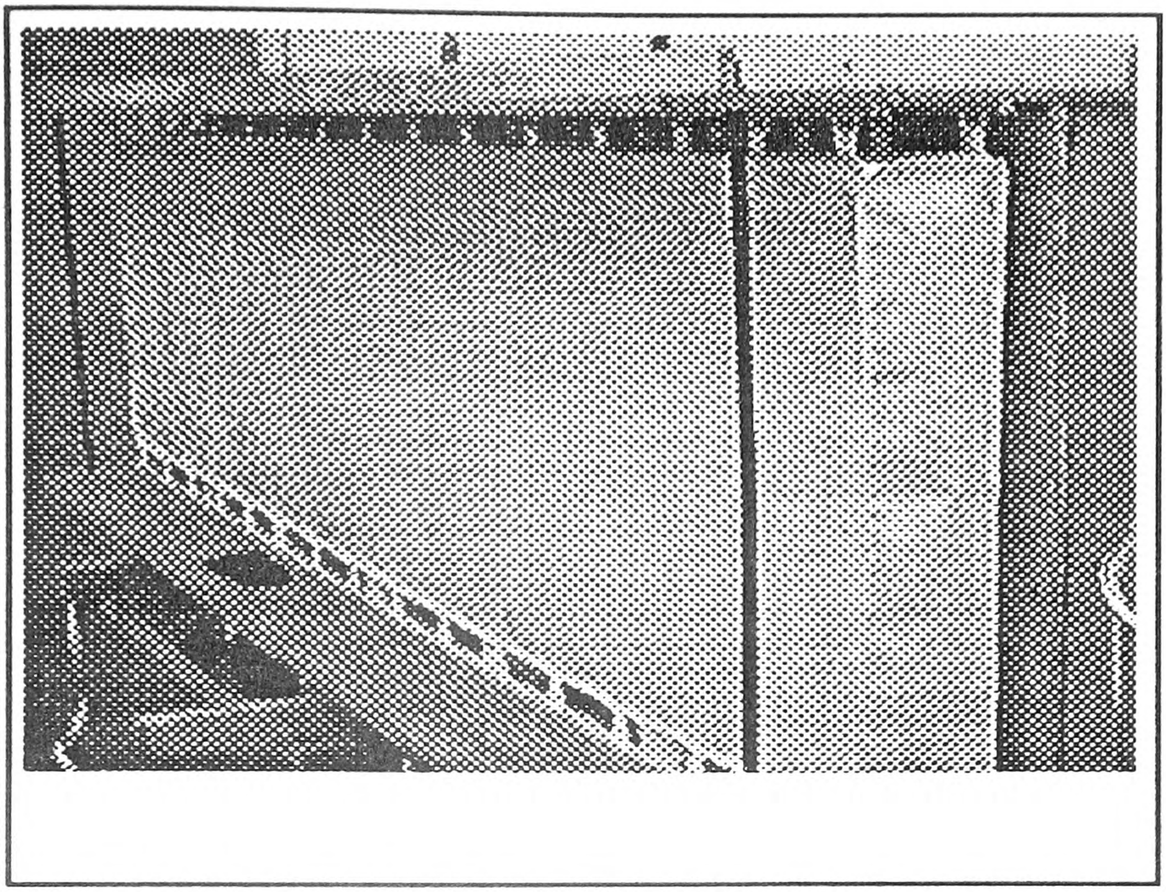


Figure 7.12 Diffuser platform/framework

7.8.1 Computer Modelling for Hoare Lea Project

Five models were simulated and solved, three of the main restaurant area, one of the restaurant and conference area arranged for seating, and one of the restaurant and conference area arranged for circulation. The SABRE computational fluid dynamics software package was used to provide 3 dimensional information for air velocities, air movement patterns and air temperatures.

The first three models investigated various displacement terminal locations, the fourth includes the three conference rooms with a greater occupancy of 350 people, and the final one introduces solar gains. The models were created using the parameters and design criteria detailed in table 7.10.

Table 7.10 Parameters and design criteria for CFD models

Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Geometry:					
Total Floor area	330 m^2	330 m^2	330 m^2	412 m^2	412 m^2
Floor to ceiling height	2.7 m	2.7 m	2.7 m	2.7 m	2.7/6.4 m
Temperature:					
Design air temperature	21 °C	21 °C	21 °C	21 °C	21 °C
Supply air temperature	19 °C	19 °C	19 °C	19 °C	19 °C
Occupants:					
Total number	150	150	150	350	350
	1/ 2.2 m^2	1/ 2.2 m^2	1/ 2.2 m^2	1/ 1.2 m^2	1/ 2.2 m^2
Ventilation:					
Total volume flow rate	4.4 m^3/s	4.8 m^3/s	4.5 m^3/s	5.6 m^3/s	5.1 m^3/s
Fresh air rate (l/s/pers)	29.3	32.2	30	16	34
Air changes per hour	17.8	19.5	18.2	18.1	7.65
Heat gains:					
Lighting	15 W/m^2	15 W/m^2	15 W/m^2	15 W/m^2	15 W/m^2
Occupants (sensible)	90 W/pers	90 W/pers	90 W/pers	90 W/pers	90 W/pers
Equipment					6000 W
Solar gain					8425 W
Supply terminals:					
Terminal height	1 m	0.9 m	0.9 m	0.9 m	0.9/1.2 m
Terminal free area	60 %	50%	various	various	various
Column supply:					
Volume flow rate	0.4 m^3/s	0.3 m^3/s	0.3 m^3/s	0.3 m^3/s	0.3 m^3/s
Face velocity	0.38 m/s	0.38 m/s	0.2 m/s	0.2 m/s	0.2 m/s
Perimeter supply:					
Total volume flow rate	2.4 m^3/s	3.63 m^3/s	3.3 m^3/s	4.4 m^3/s	3.9 m^3/s
Total length	16 m	23 m	23 m	34.7 m	26.5 m
Face velocity	0.25 m/s	0.36 m/s	0.2 m/s	0.2 m/s	0.2 m/s

7.8.2 Computer modelling results

7.8.2.1 Model 1

The results indicated that air temperature within the occupied zone stays within the design criteria and varies from 19 °C at floor level to 22 °C at head height, whilst average velocities at ankle height are between 0.11 and 0.19 m/s.

However, as with the work of the author reported in 6.6, average figures masked potential problem areas. The detailed velocity data revealed that there were problem areas with velocities in excess of 0.2 m/s. These problem areas which would cause draught discomfort to the occupants were where terminals were located in the corners of the restaurant on both flanks, resulting in a doubling of supply flow rate locally.

Subject to resolving this problem, the outcome of the first analysis was that the restaurant displacement ventilation system would achieve the design criteria.

7.8.2.2 Model 2

This was a revised displacement ventilation layout due to architectural design development with a free area of 50% to represent timber slats in front of the terminals. Whilst temperatures remained acceptable as high volume flow rates were maintained, input velocities were raised to 0.37 m/s, with unacceptably high velocities at ankle level near the supply terminals. This confirmed that care would be required to avoid aesthetic considerations compromising the design principle.

7.8.2.3 Model 3

With careful design of timber slat profiles, and avoiding convergence of supply flows at inside corners, this model confirmed that acceptable temperatures not exceeding 22 °C could be achieved without velocities in the room exceeding 0.2 m/s.

7.8.2.4 Model 4

This model extended model 3 for an occupation level of 350 people. This resulted in an increase in temperature of approximately 2 °C, but as the maximum temperature was 23.6 °C, comfort limits are still not being exceeded.

The air flow patterns and velocities were similar to those for model 3, except where, due to the way the occupants were modelled as parallel blocks of people, the air appeared to channel and increase in speed between the occupants. If such velocities did occur, the occupants would experience discomfort. However, in reality, the occupants are not a solid block, and the effect would not be so pronounced.

7.8.2.5 Model 5

This model was the same configuration as model 4, but introduced equipment and solar gains as well as additional double height circulation areas.

Under these conditions the restaurant temperatures remain below 22 °C, and in the remainder of the building are limited to 22.9 °C.

7.8.3 Operating experience

There have been some teething problems with the installation that the designers put down to lack of understanding of how the system is intended to operate by third parties. Despite the contraindications from the modelling exercise, the architects used a design of timber slatting that generated undesirable jets and uncomfortable draughts. Also, the engineers responsible for the operation of the system, being unfamiliar with the principle of displacement ventilation, had reduced the supply air temperature to increase the rate of cooling rather than increasing the air flow rate.

These problems were easily identified and remedied and the system is now performing as predicted by the computer modelling (Cullen 1999).

7.8.4 Relationship with earlier experimental work

The experimental work reported in section 6.0 identified that for a cooling load of 53 W/m^2, and an air change rate of 9, (136.7 l/s or 15 l/s per linear metre of diffuser), temperatures in the room were acceptable but near the limit of acceptability. This was achieved without excessive velocities by a good margin, but diffuser noise was apparent. Higher flow rates could not be tried due to the limitations of the air handling unit of the experimental room. It was predicted that if the diffuser design could be modified to avoid the noise problem, then the peak temperature could be reduced or the cooling load increased by increasing flow rates without detriment to the velocity regime in the occupied space.

This installation has provided an opportunity to test this prediction. Considering the worst case that was modelled, model 4 with the high occupancy conference area, the cooling load was 15W/m^2 for lighting and 75 W/m^2 for occupancy, including circulation areas, (based on 90 W per person and 1 person/m^2), a total of 90W/m^2. The air change rate was 18.1 per hour (4.4 m^3/s or 127 l/s per linear metre of diffuser).

As this was approximately twice the flow rate for a cooling load that was approximately 70% higher, the temperature was better controlled, (maximum 23.6 ^oC compared to 25.8 ^oC), whilst the velocities and noise levels were still acceptable. This modelling substantially validates the earlier experimental work.

Chapter 8

Discussion

8.0 DISCUSSION

8.1 Introduction

Skistad (1994) summarises the requirements of a displacement ventilation system as follows:

"The ventilating air has two tasks:

- *to produce air quality acceptable to the occupants of the room*
- *to remove surplus heat from the room*

These two tasks put different demands on supply unit performance. When air quality is the aim, the air should be provided in the gentlest way, with the least possible mixing. This is best obtained by discharge through a filter mat. When the aim is to remove surplus heat, the supply air has to be cooler than the room air. In this case, entrainment of room air into the primary air is necessary to avoid a cold draught along the floor. The larger the under-temperature, the more entrainment is needed. However, when room air is mixed into the primary air, we sacrifice air quality. In fact, the ultimate case is that we produce so much mixing in the room air that we end up with dilution ventilation.

In most practical cases, ventilation must provide both air quality and heat removal".

Since this was written, practitioners seem to have taken a different view (Alamdari 1995, Arnold 1995,1996), with a number of installations utilising ceiling mounted static cooling devices in combination with displacement ventilation.

The philosophy that ventilation should satisfy these two requirements of providing acceptable air quality whilst removing surplus heat, presents the designer with a real challenge in practice.

The alternative philosophy is that ventilation for air quality and temperature control for thermal comfort are mutually exclusive objectives and different systems or solutions are required for each objective. Only very occasionally will one system satisfy both objectives.

This second philosophy is reflected in the displacement theory developed by BSRIA (BSRIA TM 2/90, BSRIA TN 3/93). It is in response to this understanding of the problem that the market trend has been towards the use of static cooling devices in the ceiling to supplement the perceived restriction on the amount of cooling available from a displacement ventilation system (BSRIA COP 17/99). The author acknowledges that this solution has been developed in a commercial situation where a design solution is optimised on reducing the risk of overheating possibly at the expense of air quality. The former is more readily discernible by the occupants and more easily measured by the litigant.

The problem with adopting the two system approach arises if one system adversely affects the other. This problem, in principle, is familiar in the "Heating, Ventilating and Air Conditioning" industry. In pursuit of the two system approach designers have in the past, installed separate heating and cooling systems in buildings. Where the control of such systems has been inadequate, both systems have been found to be operating simultaneously trying to cancel each other out. This problem has been so commonplace, that it was recognised by the novelist Tom Sharpe in his book "Ancestral Vices" (1980). In describing a University Library building he identifies that "*...during spring and autumn it was essential to run both heating and cooling systems at the same time or to alternate between them extremely abruptly to maintain even a moderately comfortable atmosphere*".

The use of chilled ceilings in conjunction with displacement ventilation presents the same problem of conflict of objectives when the buoyancy driven ventilation flow is counteracted by the downward convection from the chilled ceiling.

8.2 Air quality issues

A brief consideration of the basic principles of buoyancy driven ventilation as outlined in Chapter 1, indicates the possibility of significant downward convective currents from chilled ceiling devices compromising air quality. This theory was tested as part of the smoke visualisation procedures that were being used to design the experimental process. The smoke visualisation confirmed that downward convection plumes were occurring that were powerful enough to return the previously extracted air to floor level in the space.

This exercise had been carried out in response to concerns raised by Koganei (1991), Neilson (1993) and Alamdari (1994), and confirmed that downward convection was of concern. The smoke visualisation tests that were reported by Dickson (1994) suggested that upward convection from occupants and office machinery was stronger than the downward convection plumes. Dickson concludes that in most circumstances the downdraught is overcome by the upward convection forces and does not constitute a problem. From the smoke visualisation work carried out by the author, this conclusion is challenged as it was found that the reverse was the case, with the downward convection only being countered effectively in the presence of strong heat sources such as from the heating pads used on the simulated photocopier. In this situation however, it was found that the velocities were sufficiently high to causes the airsteam to "bounce back" rather than spread across the ceiling, with contaminated air returning to the occupied space.

The concerns raised by Koganei (1991), Neilson (1993) and Alamdari (1994) were in respect of cold room surfaces such as external windows and walls. The vulnerability of displacement flow to disturbances by movement and draught are also identified (Wyatt 1993). The similar concerns raised by the author were in respect of the disturbance to displacement flow caused by the simultaneous use of chilled ceiling devices. The argument is presented that this latter effect is a more significant problem than those previously identified.

To address the problem of "naturally" cold surfaces, there is evidence that this will become less of a problem in buildings in the near future. Following consultation with the industry, the Building Regulation Division of the DETR proposes that the following measures will be incorporated into the next revision of the Building Regulations, Approved Document L (King 1999):

- Increasing levels of thermal insulation of the fabric, supplemented by more robust methods of checking compliance such as the use of thermal imaging on completion of construction.

- Increasing levels of thermal performance of glazing systems.

Similarly the problems of disruption from external wind forces should diminish in the future due to the initiatives from the DETR (King 1999, Brundrett 1997) namely:

- Increasing standards of air tightness in construction supplemented by more robust methods of checking compliance such as whole building pressure testing on completion of construction.

These factors will increase the opportunities for the successful adoption of stand alone displacement ventilation systems, and leave the selection of chilled ceilings by designers as the only remaining barrier to the effective use of a displacement ventilation system.

Proponents of the use of static cooling devices in combination with displacement ventilation are dismissive of the cooling potential of the ventilation system, preferring to treat the two elements as separate systems.

The smoke visualisation confirmed that downward convection plumes were occurring that were powerful enough to return the extracted air to floor level in the space. This finding confirmed the need to investigate other solutions to improve the performance of systems incorporating displacement ventilation techniques, regardless of the anticipated building fabric improvements identified above.

The comparison of temperature profile results from experiments 3 and 4 (Figure 6.32) indicates a distinct change of gradient at the interface between the displacement flow regime and the mixing zone. The higher air flow rates via the textile diffuser for experiment 3 indicate that there is a displacement flow regime established for the full height of the occupied zone (1.75 m). The resulting uniform good air quality regime throughout the occupied zone that is implied by this observation reduces any dependency on the personalised boundary layer theory proposed by Wyatt (1993) to ensure good air quality. Concerns raised by Sandberg (1992), Mundt (1993), Akimoto (1995), over the breakdown of the displacement regimes due to transient disturbances from movement of building occupants are also likely to be ameliorated by the robustness of the regime achieved by higher air flow rates.

It is demonstrated that the objective of providing and maintaining good indoor air quality can be achieved by displacement ventilation with the use of textile diffusers. Whether the simultaneous objective of providing thermal comfort can also be achieved without resorting to supplementary cooling devices is the subject of further discussion.

8.3 Thermal comfort issues

Although thermal comfort is subjective to the individual, for a given range of conditions the majority of the population of a building (95%) may be satisfied (ISO 7730, 1995). The variables that influence thermal comfort, used to produce the Predicted Mean Vote (PMV) index, are air temperature and temperature gradient, radiant temperature, air movement, relative humidity, level of clothing, and level of activity. In order to produce PMV figures for the experimental work carried out, a relative humidity of 50% has been assumed and clothing and activity levels of 0.6 clo and 1.2 met respectively, being typical levels for sedentary occupants.

In Section 6.7 in analysis of experiments 3 and 4 comparisons between the performance, at 53 W/m^2 cooling load, of two systems are made. Experiment 3 was for the textile diffuser handling 9 air changes per hour and Experiment 4 was for the standard displacement diffuser handling 3.5 air changes per hour with supplementary cooling by chilled panel.

Although both systems almost comply with the ISO 7730 requirement of remaining between –0.5 and +0.5, the profiles are quite different (Figure 6.34). At the lower end of the range, both systems drift beyond the –0.5 limit, with the chilled panel system drifting the furthest. This is a result of higher velocities from the standard diffusers, and the effect of radiant cooling from the ceiling. The fact that the lower limit is passed does not necessarily mean that occupants will be dis-satisfied with either system, given concerns identified over the reliability of the PMV index (Oseland 1993,1994,1995, Alfano 1995, Humphreys 1998).

With the demonstrated ability to supply air at higher volume flow rates, the possibility of introducing the supply air at a higher temperature to meet a given cooling duty is introduced. A one degree (K) increase in air supply temperature would bring the floor level values of PMV above –0.5 for the textile diffuser system.

The PMV profiles for both systems follow a very similar gradient rising to a value approaching zero at a height of approximately 1.1 m. Above this height the PMV value for the chilled panel system remains close to zero to the full height of the room. The PMV profile for the textile diffuser system continues to a value of +0.4 at a height of approximately 1.7 m after which it remains close to 0.4 to the full height of the room. With reference to the temperature profiles, (Figure 6.32) it can be seen that the PMV results are being strongly influenced by the air temperature in the room. Here the degree of rise from floor to ceiling is not ideal. This is a result of a lack of radiant cooling.

As recognised by Kulpmann (1993) this convective/radiant imbalance is not unusual for a cooling situation where the heat transfer medium is primarily air and advice is given in CIBSE Guide A (1986) to help designers take account of this. It must be recognised, however, that by conducting the comparative exercise in the same test room, the textile diffuser is not being used in the best room arrangement. Without the need for chilled panels in the ceiling the panels, which when not in use are simply a thermally lightweight barrier to heat dissipation, can be dispensed with to bring an element of "natural" radiant cooling to bear. There is scope to consider the use of the textile diffuser for high volume flow rate displacement ventilation as part of a mixed mode strategy as promoted by innovative designers such as Arnold (1995).

8.4 Others issues

As identified in the literature displacement ventilation offers the opportunity to reduce energy consumption in addition to improving air quality (Chen Q 1991, Nielson P V 1993, Alamdari F et al 1994, Skistad H 1994). The case studies reviewed in Chapter 7 indicated that there are installation and maintenance cost benefits in addition to low energy cost benefits. The three separate studies have illustrated these factors (Section 7.1). The studies were life cycle cost comparisons for various air conditioning strategies and were carried out by an installation and maintenance contractor, a consulting engineer and a cost consultant. The main findings, tabulated in Table 7.1-7.5, suggest that financial benefits can be added to the case for increasing the scope for displacement-ventilation-only installations.

The anti-condensation work carried out in the same test facility as the experimental work for this thesis (Martin 1997), and in operational buildings by Butler (1997) was inconclusive about the scale of the problem, or in fact whether there was a problem at all. The anti-condensation control strategies identified are the same as may be used to avoid condensation on the coiling coils of ceiling mounted fan coil units. Although these fan coil units are fitted with drained drip trays, operational experience of blocked drains due to shallow drainage falls within the constraint of the suspended ceiling void makes anti-condensation strategies desirable.

In the case of chilled panels, and to a lesser extent chilled beams, drip trays are not a practical option for condensation removal, making anti-condensation measures essential. The comparison with ceiling mounted fan coils can be taken further. Although fan coils are widely used as indicated by the case studies reported in Section 7.1, they do have inherent problems, particularly in the modern "electronic age" where most office workers have a desk top personal computer that is vulnerable to water damage. The fan coil system, using water as the transfer medium, involves the installation of heating and cooling water circulation pipes, i.e. each unit has four pipe connections. The condensation problem identified above is therefore only part of the potential for water damage problems.

Every pipe and more specifically every joint and connector is a potential source of water leakage during the life of the installation. Although there is less pipework involved, as there is only a cooling circuit, this will also be an inherent disadvantage with the use of ceiling mounted static cooling devices.

As already stated, fan coil units are widely used despite the inherent leakage problem. Good design principles would suggest the avoidance of fan coil units in offices utilising electronic equipment, but in practice other factors come to bear. In many instances a cooling system is installed in an existing building, which ironically, is often in response to cooling loads imposed by the increase in the use of electronic machinery. In this situation an inherently safer all-air system, where air is the energy transfer medium, the size of ductwork required cannot be accommodated within the existing building structure. The large ductwork is required as air is not a good energy transfer medium when compared with water, (approximately 1/4 of the specific heat carrying capacity, and approximately 1/800 th of the density).

Even in new buildings, where space can be allowed in the design for the ductwork of an all-air system, it may not be done in practice as this adds to the cost of the building. Fan coils are often selected because they are lower in capital cost and the potential problems identified above will not be experienced by the designer or installer, but by the operator of the building over time. The lack of linkage between designer and user lies at the root of many building related problems in the experience of the author.

It has been argued here that fan coil units should only be used as a last resort when there is a cooling requirement in a building. It is a good design principle to design out maintenance. For the same reason, when a displacement ventilation system is being considered for the associated air quality benefits, the use of supplementary static cooling devices in the ceiling should only be used as a last resort.

The author recognises that product manufacturers fund much research including much of that conducted by BSRIA. This tends to influence the research, not in terms of the results and research output, but in terms of the questions being asked. In the case of the Displacement Ventilation Code of Practice project, the manufacturers were looking for industry standard guidance on how to use their products to best effect, and how to overcome any operational problems experienced in their use. They would be less likely to suggest that the research team investigated alternative techniques that did not use their products. The work for this thesis has therefore added an entirely original element to the previously established programme of work.

8.5 Limitations of experimental programme and suggestions for improvements

8.5.1 Limitations of experimental programme

For the researcher, many problems associated with indoor air quality are particularly challenging as they span many disciplinary boundaries (i.e. architecture, building science, building engineering services, occupational health and human behaviour and physiology). Additionally air quality is influenced by many building specific variables such as layout, organisations occupying the building, management styles, and preferences of individual occupants.

The work for this thesis has acknowledged many of these factors whilst aiming to establish the pure performance characteristics of the systems under scrutiny. The impact of most of these factors will be identified as the subject for further work.

The experimental programme was carried out in a test facility that was designed and used for experimental work associated with the use of ceiling mounted static cooling devices in combination with displacement ventilation. The programme was funded at various stages by the DETR, CIBSE, BSRIA, and the manufacturers of displacement ventilation diffusers and chilled beams and panels. The aim of the project was to establish the performance characteristics of displacement ventilation systems in combination with chilled ceilings to produce a Code of Practice for designers.

The facility was made available largely at the discretion of BSRIA, although the University of Glamorgan and the manufacturer of textile diffusers contributed some funding, and inevitably there were restrictions on the time available for experiments to be carried out. Any necessary alterations to the test rooms needed to be reversible so that the room could continue to be used for the main programme of experimental work. This limited the range of experimental variations that could be considered, and other room configurations may have otherwise been considered. For example, some experimental work without a suspended ceiling could have been carried out had it not been too disruptive to the main programme. Also the opportunity to carry out tracer gas analysis to quantify the air quality characteristics was denied due to time constraints.

These problems are inherent in the use of physical modelling as an experimental method. The cost of establishing a test room and the space it occupies will always put time pressure on the researcher to release the space if not the facility itself for other purposes. This problem was identified in Chapter 2.

Against this, use of the BSRIA facility gave the opportunity to utilise better monitoring equipment than would otherwise have been possible. Access to directly comparable data for analysis of results and formulation of the experimental programme were additional benefits. Also the value of the opportunity to feed the research output directly into the industry Code of Practice was recognised by the author.

Smoke visualisation of the discharge of air through the textile diffusers would have been useful but was not carried out due to concerns that entrapment of smoke particles by the textile material would influence subsequent experimental work with the diffuser.

The ventilation plant associated with the test room was selected to provide the volume flow rates normally associated with the use of displacement ventilation. This placed further limitations on the scope of the experimental work, and the flow rates for experiment three were at the upper limit of the capacity of the system. The velocity profile shown in Figure 6.33 suggests that there is scope for further increases in air supply rates. The installation of textile diffusers identified in Section 7.8 has taken the supply rates higher than this, but this installation has not been objectively appraised to date.

8.5.2 Suggestions for improvements

Particular aspects of the experimental work that could be improved in any further study can be identified as follows:

- The use of motorised instrument stands would reduce the need for a stabilisation period following the entry of the experimenter to the room to re-locate the stand on the measuring grid between readings. This would reduce the uncertainty over whether the stabilisation period was long enough, and reduce the length of the experimental period.

- The use of subjects in the test room would have added the opportunity for occupant feedback on conditions in the room, which would add another dimension to the analysis, based on the PMV index.

Chapter 9

Conclusions And Further Work

The main aim of this thesis has been to investigate the effectiveness of displacement ventilation in providing good indoor air quality when used in conjunction with supplementary cooling devices, and to assess alternative techniques for dealing with higher heat loads by displacement ventilation alone. This chapter presents the conclusions that may be drawn from the results obtained, and recommendations for further research that will strengthen and build on these conclusions.

9.1 Conclusions

1. When a chilled ceiling device is used to provide supplementary cooling in conjunction with a displacement ventilation system, the resulting downward convection plumes will disrupt the buoyancy driven displacement flow, reducing ventilation effectiveness and hence indoor air quality. Further, if the chilled ceiling devices operate following a period of operation of the displacement ventilation alone, the displaced 'contaminated' air is 'dumped' or re-circulated back into the occupied zone.

2. The 'dumping' effect described in 1 above is most pronounced when the chilled ceiling device is of the chilled beam type. The chilled panel does not produce such a strong effect, and with care over the construction of the ceiling this effect can be minimised. It is unlikely in practice that it can be eliminated completely and it is concluded that displacement ventilation cannot be achieved in practice where ceiling mounted supplementary cooling devices are used. Systems currently in use and described as displacement ventilation with ceiling mounted supplementary cooling devices are in fact mixing ventilation systems delivered

via displacement ventilation diffusers with ceiling mounted supplementary cooling devices.

3. Textile diffusers show great potential for use as displacement ventilation supply diffusers increasing the number of buildings that can benefit from displacement ventilation. However, care is required in their design to avoid problems of noise generation. The high volume flow rates achievable with the use of textile diffusers introduces the concept of a "high flow" displacement ventilation system, in contrast to the "standard flow" displacement ventilation currently utilised for commercial building applications.

4. When used for displacement ventilation, textile diffusers can be used for cooling loads up to 50 W/m^2 without the assistance of supplementary cooling devices. At this load, using PPD/PMV as indicators, thermal comfort is comparable with a conventional displacement ventilation system assisted by a supplementary cooling system in a 40:60 ratio.

5. The demonstrated ability of the textile diffuser to create a relatively robust displacement flow regime at high volume flow rates makes it particularly suitable for applications where strong odours or levels of contamination are produced, and where segregation of the occupants from the contaminants is required.

6. The use of a textile diffuser for displacement ventilation significantly reduces the size of the draught zone in front of the diffuser. This increases the effective useful floor area, making the textile diffuser a better diffuser option even when

high flow rates are not required, or when supplementary cooling devices are going to be used.

9.2 Further work

The use of textile diffusers for displacement ventilation for cooling loads up to 50 W/m^2 has been demonstrated to have certain merits over the use of other diffuser types requiring supplementary cooling devices in the ceiling. However these conclusions have been based on physical modelling in one test room facility, using instrumentation to measure temperatures and velocities. These results have been converted to standard comfort indices for comparison with other systems.

The work has clearly demonstrated the technical feasibility of this application. However, the perceived benefits, namely good air quality and low energy consumption whilst maintaining thermal comfort, are deduced rather than measured. This means that there is considerable scope for further work to remove uncertainty in these areas.

The performance of the system in use in an operational building needs to be monitored and assessed. A range of monitoring techniques will be required to address the diverse criteria of thermal comfort, air quality and energy consumption.

The question of thermal comfort of the occupants requires objective and subjective treatment. The objective analysis for comparison with Standards can be provided by the same physical measurement techniques used in the experimental test room, as all the equipment is readily transportable. The subjective analysis to ensure occupant satisfaction can be achieved with the use of questionnaire or interview based surveys of the occupants of a building using this system. The occupants can also assess air quality as part of an occupant survey, particularly where contaminants are readily discernible by the occupants as is the case in buildings where smoking is permitted.

Most office buildings do not have readily detected contaminants, reducing the effectiveness of occupant surveys in assessing air quality. In these buildings, instrumentation to monitor a contaminant level such as carbon dioxide can be used to assess the ventilation effectiveness. Alternatively tracer gas techniques may be used.

The issue of energy consumption can be addressed by analysing the actual energy performance of a building in use over a full 12 month period. Alternatively, computational modelling techniques are available to simulate the operation of a building in terms of the energy performance of the environmental systems.

The only installation currently identified as using this technique is serving a conference facility with a restaurant area as identified in Section 7.8. In the absence of any other opportunity this building could be used as the basis for this proposed monitoring work. The air supply rates for this building are higher by a factor of approximately two than those assessed during the experimental work for this thesis, presenting an opportunity to re-appraise the cooling performance of the technique. As the building operator allows smoking in the building, it also presents a good opportunity for assessing the segregation of smokers and non-smokers. This could lead to applications in leisure and retail buildings where customers smoke and staff need protection from the smoke.

With the possibility of use in leisure and retail buildings there is also scope for incorporating the textile diffusers directly into the decorative finishes of the occupied spaces such as within bar frontages or under bench seating.

However, the main application for displacement ventilation is currently in commercial office buildings. Particularly in respect of thermal comfort, the nature of occupancy is significant and monitoring in other types of building would not be reliably transferable. It is therefore important to have a textile diffuser system installed and monitored in an office building.

Although the use of comfort indices indicated comparable performance for the textile diffusers, the temperature gradient in the room was on the limit of acceptability. By conducting the tests in a test room set up for testing chilled ceilings, the optimum performance of the system was not established, with the test room scenario probably being the worst case. It is likely that the best comfort conditions will be established when the system is used without a suspended ceiling, taking advantage of the thermal mass of the ceiling, with or without the use of night cooling. This needs to be examined, ideally in an operational building rather than a test facility, where the thermal mass may be difficult to model.

The experimental work has addressed cooling loads of the nature and magnitude of typical internal casual gains (machinery, occupants and lighting) for a commercial office application. No account has been taken of the problem of direct or indirect solar gain. The nature and magnitude of these gains and their impact on the occupied space can be significantly varied by the design of the fabric of the building. Further work is required to assess the relative merits of dealing with the issue of solar gains in the design of the building, i.e. shading and thermal mass or dealing with them through the use of air conditioning systems. There may be scope for dealing with these additional gains with the use of a "high volume" displacement ventilation system, when some care is taken to minimise solar gains, particularly through glazing.

Finally, further physical modelling is required on a fine measurement grid to establish the nature of the discharge profile in close proximity to the diffuser, and hence the size of the draught zone for the diffuser.

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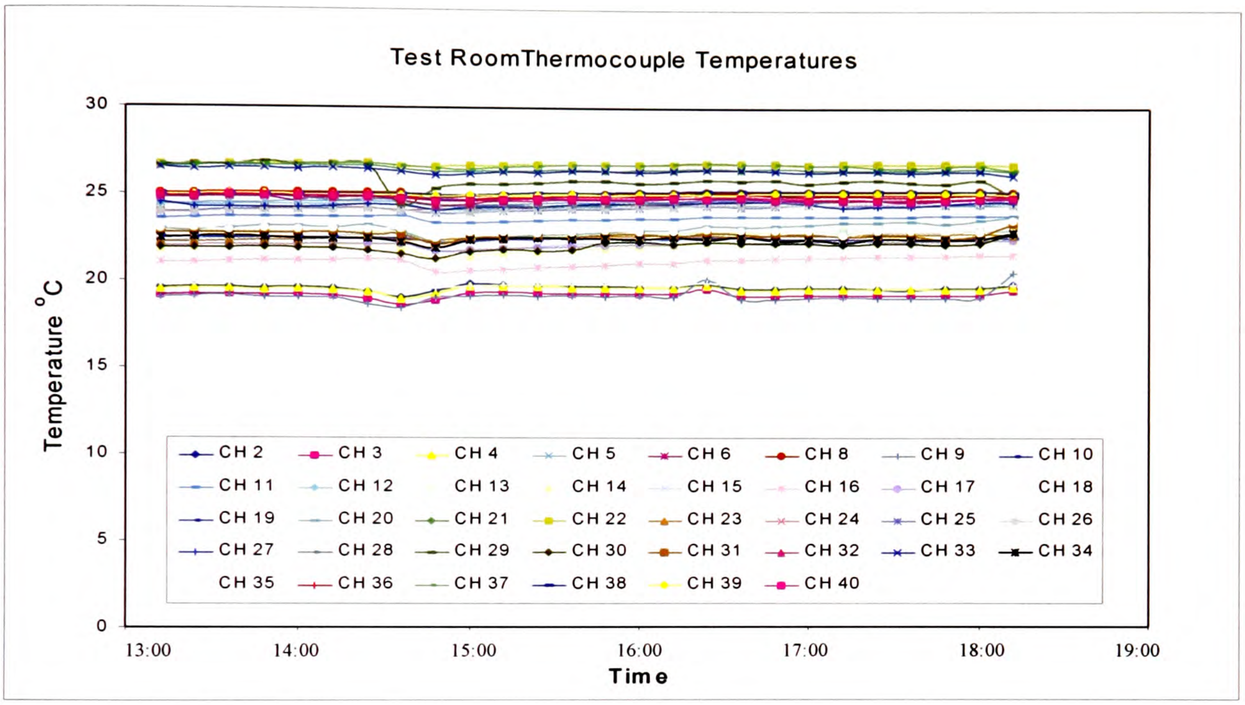
APPENDIX I

FEASIBILITY STUDY

DATA

The graph below shows a 40 channel plot for the 40 thermocouples located around the test room, as listed in Table 5.3. This shows the temperature profile for the room during the 9.3 air change trial for the textile diffuser.



The table on the following pages shows the full data capture for the temperature and velocity conditions in the test room during the 9.3 air change trial for the textile diffuser.

TEST 1: Displacement ventilation with sock diffusers 9.3 air changes/hr
Electrical Load 60 W/m^2 (50 W/m^2)

Time	Ch'l	Grid	Grid	Order	Globe	Mean	Turb	Mean	corrected	corrected
		x-axis	y-axis		(°C)	(m/s)	(%)	(°C)	(m/s)	(°C)
13:00	1	17	10	1	21.69	0.026	45.1	20.3	0.02487	20.114
13:00	2	17	10	1	21.69	0.033	38.1	21.5	0.03785	19.7883
13:00	3	17	10	1	21.69	0.037	20.8	22.6	0.044852	22.122
13:00	4	17	10	1	21.69	0.036	16	24	0.040861	23.5154
13:00	5	17	10	1	21.69	0.039	10.2	24	0.049238	23.7624
13:00	6	17	10	1	21.69	0.03	38.5	24.6	0.034173	24.1497
13:00	7	1	10	1	22.06	0.037	52	20.2	0.042641	19.9006
13:00	8	1	10	1	22.06	0.038	36.1	21.5	0.047905	20.8496
13:00	9	1	10	1	22.06	0.074	34.9	22.2	0.07881	21.6653
13:00	10	1	10	1	22.06	0.102	22.3	22.7	0.103298	22.1208
13:00	11	1	10	1	22.06	0.068	26.9	23.4	0.078098	23.1456
13:00	12	1	10	1	22.06	0.042	48.6	24.4	0.047073	23.9461
13:00	1	17	1	1	21.69	0.026	45.1	20.3	0.02487	20.114
13:00	2	17	1	1	21.69	0.033	38.1	21.5	0.03785	19.7883
13:00	3	17	1	1	21.69	0.037	20.8	22.6	0.044852	22.122
13:00	4	17	1	1	21.69	0.036	16	24	0.040861	23.5154
13:00	5	17	1	1	21.69	0.039	10.2	24	0.049238	23.7624
13:00	6	17	1	1	21.69	0.03	38.5	24.6	0.034173	24.1497
13:00	7	1	1	1	22.06	0.037	52	20.2	0.042641	19.9006
13:00	8	1	1	1	22.06	0.038	36.1	21.5	0.047905	20.8496
13:00	9	1	1	1	22.06	0.074	34.9	22.2	0.07881	21.6653
13:00	10	1	1	1	22.06	0.102	22.3	22.7	0.103298	22.1208
13:00	11	1	1	1	22.06	0.068	26.9	23.4	0.078098	23.1456
13:00	12	1	1	1	22.06	0.042	48.6	24.4	0.047073	23.9461
13:22	1	16	10	2	21.86	0.026	31.2	19.7	0.02487	19.5441
13:22	2	16	10	2	21.86	0.024	46.3	21.2	0.029109	19.2108
13:22	3	16	10	2	21.86	0.038	5.3	22.8	0.045838	22.3156
13:22	4	16	10	2	21.86	0.037	5.4	24	0.041899	23.5154
13:22	5	16	10	2	21.86	0.049	27.3	23.9	0.058735	23.6672
13:22	6	16	10	2	21.86	0.041	33	24.5	0.045713	24.053
13:22	7	2	10	2	22.75	0.047	32.9	19.8	0.051706	19.5162
13:22	8	2	10	2	22.75	0.05	35.3	20.9	0.05978	20.2737
13:22	9	2	10	2	22.75	0.127	25.9	20.8	0.132605	20.3184
13:22	10	2	10	2	22.75	0.061	47.5	23.2	0.066439	22.6083
13:22	11	2	10	2	22.75	0.108	22.2	23.1	0.11745	22.8476
13:22	12	2	10	2	22.75	0.065	38.7	24.6	0.069073	24.1396
13:22	1	16	1	2	21.86	0.026	31.2	19.7	0.02487	19.5441
13:22	2	16	1	2	21.86	0.024	46.3	21.2	0.029109	19.2108
13:22	3	16	1	2	21.86	0.038	5.3	22.8	0.045838	22.3156
13:22	4	16	1	2	21.86	0.037	5.4	24	0.041899	23.5154
13:22	5	16	1	2	21.86	0.049	27.3	23.9	0.058735	23.6672
13:22	6	16	1	2	21.86	0.041	33	24.5	0.045713	24.053
13:22	7	2	1	2	22.75	0.047	32.9	19.8	0.051706	19.5162
13:22	8	2	1	2	22.75	0.05	35.3	20.9	0.05978	20.2737
13:22	9	2	1	2	22.75	0.127	25.9	20.8	0.132605	20.3184
13:22	10	2	1	2	22.75	0.061	47.5	23.2	0.066439	22.6083
13:22	11	2	1	2	22.75	0.108	22.2	23.1	0.11745	22.8476
13:22	12	2	1	2	22.75	0.065	38.7	24.6	0.069073	24.1396
13:38	1	15	10	3	21.9	0.029	38.4	20.5	0.028028	20.3039
13:38	2	15	10	3	21.9	0.047	20.9	21.2	0.051446	19.9808
13:38	3	15	10	3	21.9	0.038	5.3	22.9	0.045838	22.4124

13:38	4	15	10	3	21.9	0.036	7.9	24	0.040861	23.5154
13:38	5	15	10	3	21.9	0.037	34	24.2	0.047339	23.9526
13:38	6	15	10	3	21.9	0.052	19.6	24.7	0.057253	24.2464
13:38	7	3	10	3	23	0.023	35.1	19.8	0.02995	19.5162
13:38	8	3	10	3	23	0.048	24.2	21.6	0.057801	20.9456
13:38	9	3	10	3	23	0.041	32.4	22.8	0.045315	22.2425
13:38	10	3	10	3	23	0.045	51.4	23.8	0.052055	23.1932
13:38	11	3	10	3	23	0.09	26	23.3	0.099742	23.0463
13:38	12	3	10	3	23	0.096	22.8	23.9	0.098724	23.4624
13:38	1	15	1	3	21.9	0.029	38.4	20.5	0.028028	20.3039
13:38	2	15	1	3	21.9	0.047	20.9	21.2	0.051446	19.9808
13:38	3	15	1	3	21.9	0.038	5.3	22.9	0.045838	22.4124
13:38	4	15	1	3	21.9	0.036	7.9	24	0.040861	23.5154
13:38	5	15	1	3	21.9	0.037	34	24.2	0.047339	23.9526
13:38	6	15	1	3	21.9	0.052	19.6	24.7	0.057253	24.2464
13:38	7	3	1	3	23	0.023	35.1	19.8	0.02995	19.5162
13:38	8	3	1	3	23	0.048	24.2	21.6	0.057801	20.9456
13:38	9	3	1	3	23	0.041	32.4	22.8	0.045315	22.2425
13:38	10	3	1	3	23	0.045	51.4	23.8	0.052055	23.1932
13:38	11	3	1	3	23	0.09	26	23.3	0.099742	23.0463
13:38	12	3	1	3	23	0.096	22.8	23.9	0.098724	23.4624
13:50	1	14	10	4	21.93	0.054	26.6	20.5	0.054346	20.3039
13:50	2	14	10	4	21.93	0.044	27.9	21.2	0.048533	19.9808
13:50	3	14	10	4	21.93	0.041	10.9	22.7	0.048793	22.2188
13:50	4	14	10	4	21.93	0.034	14.6	23.9	0.038785	23.4196
13:50	5	14	10	4	21.93	0.035	20	24.2	0.04544	23.9526
13:50	6	14	10	4	21.93	0.041	28.3	25.1	0.045713	24.6332
13:50	7	4	10	4	22.66	0.036	37	19.8	0.041734	19.5162
13:50	8	4	10	4	22.66	0.059	23.6	21.6	0.068686	20.9456
13:50	9	4	10	4	22.66	0.039	37.9	22.6	0.043285	22.0501
13:50	10	4	10	4	22.66	0.034	15.5	23.8	0.042166	23.1932
13:50	11	4	10	4	22.66	0.038	28.8	24	0.048584	23.7417
13:50	12	4	10	4	22.66	0.036	28.6	25.4	0.041334	24.9135
13:50	1	14	1	4	21.93	0.054	26.6	20.5	0.054346	20.3039
13:50	2	14	1	4	21.93	0.044	27.9	21.2	0.048533	19.9808
13:50	3	14	1	4	21.93	0.041	10.9	22.7	0.048793	22.2188
13:50	4	14	1	4	21.93	0.034	14.6	23.9	0.038785	23.4196
13:50	5	14	1	4	21.93	0.035	20	24.2	0.04544	23.9526
13:50	6	14	1	4	21.93	0.041	28.3	25.1	0.045713	24.6332
13:50	7	4	1	4	22.66	0.036	37	19.8	0.041734	19.5162
13:50	8	4	1	4	22.66	0.059	23.6	21.6	0.068686	20.9456
13:50	9	4	1	4	22.66	0.039	37.9	22.6	0.043285	22.0501
13:50	10	4	1	4	22.66	0.034	15.5	23.8	0.042166	23.1932
13:50	11	4	1	4	22.66	0.038	28.8	24	0.048584	23.7417
13:50	12	4	1	4	22.66	0.036	28.6	25.4	0.041334	24.9135
14:02	1	13	10	5	21.99	0.028	27.3	20.8	0.026976	20.5888
14:02	2	13	10	5	21.99	0.034	24.3	21.6	0.038821	20.2695
14:02	3	13	10	5	21.99	0.041	7	22.8	0.048793	22.3156
14:02	4	13	10	5	21.99	0.034	22.1	23.9	0.038785	23.4196
14:02	5	13	10	5	21.99	0.052	32.7	23.6	0.061584	23.3818
14:02	6	13	10	5	21.99	0.038	29.3	24.9	0.042566	24.4398
14:02	7	5	10	5	22.45	0.054	30.3	21	0.058051	20.6695
14:02	8	5	10	5	22.45	0.044	32.9	21.5	0.053842	20.8496
14:02	9	5	10	5	22.45	0.037	41.3	22.7	0.041255	22.1463
14:02	10	5	10	5	22.45	0.033	18.1	23.8	0.041267	23.1932
14:02	11	5	10	5	22.45	0.037	15.3	23.8	0.047601	23.543
14:02	12	5	10	5	22.45	0.039	20.4	25	0.044204	24.5266
14:02	1	13	1	5	21.99	0.028	27.3	20.8	0.026976	20.5888

14:02	2	13	1	5	21.99	0.034	24.3	21.6	0.038821	20.2695
14:02	3	13	1	5	21.99	0.041	7	22.8	0.048793	22.3156
14:02	4	13	1	5	21.99	0.034	22.1	23.9	0.038785	23.4196
14:02	5	13	1	5	21.99	0.052	32.7	23.6	0.061584	23.3818
14:02	6	13	1	5	21.99	0.038	29.3	24.9	0.042566	24.4398
14:02	7	5	1	5	22.45	0.054	30.3	21	0.058051	20.6695
14:02	8	5	1	5	22.45	0.044	32.9	21.5	0.053842	20.8496
14:02	9	5	1	5	22.45	0.037	41.3	22.7	0.041255	22.1463
14:02	10	5	1	5	22.45	0.033	18.1	23.8	0.041267	23.1932
14:02	11	5	1	5	22.45	0.037	15.3	23.8	0.047601	23.543
14:02	12	5	1	5	22.45	0.039	20.4	25	0.044204	24.5266
14:13	1	12	10	6	22.12	0.019	27.5	19.9	0.017501	19.7341
14:13	2	12	10	6	22.12	0.04	13.3	21.7	0.044648	19.4033
14:13	3	12	10	6	22.12	0.035	22.4	22.9	0.042882	22.4124
14:13	4	12	10	6	22.12	0.028	19.8	23.9	0.032558	23.4196
14:13	5	12	10	6	22.12	0.037	13.3	24.2	0.047339	23.9526
14:13	6	12	10	6	22.12	0.041	23.9	24.9	0.045713	24.4398
14:13	7	6	10	6	22.49	0.036	43.3	20.5	0.041734	20.1889
14:13	8	6	10	6	22.49	0.038	33.3	21.7	0.047905	21.0416
14:13	9	6	10	6	22.49	0.042	57.2	22.5	0.04633	21.9539
14:13	10	6	10	6	22.49	0.049	53.2	23.2	0.055651	22.6083
14:13	11	6	10	6	22.49	0.045	51.4	23.5	0.055471	23.245
14:13	12	6	10	6	22.49	0.032	35.2	25.1	0.037508	24.6233
14:13	1	12	1	6	22.12	0.019	27.5	19.9	0.017501	19.7341
14:13	2	12	1	6	22.12	0.04	13.3	21.7	0.044648	19.4033
14:13	3	12	1	6	22.12	0.035	22.4	22.9	0.042882	22.4124
14:13	4	12	1	6	22.12	0.028	19.8	23.9	0.032558	23.4196
14:13	5	12	1	6	22.12	0.037	13.3	24.2	0.047339	23.9526
14:13	6	12	1	6	22.12	0.041	23.9	24.9	0.045713	24.4398
14:13	7	6	1	6	22.49	0.036	43.3	20.5	0.041734	20.1889
14:13	8	6	1	6	22.49	0.038	33.3	21.7	0.047905	21.0416
14:13	9	6	1	6	22.49	0.042	57.2	22.5	0.04633	21.9539
14:13	10	6	1	6	22.49	0.049	53.2	23.2	0.055651	22.6083
14:13	11	6	1	6	22.49	0.045	51.4	23.5	0.055471	23.245
14:13	12	6	1	6	22.49	0.032	35.2	25.1	0.037508	24.6233
14:23	1	11	10	7	22.28	0.036	12.3	20	0.035397	19.829
14:23	2	11	10	7	22.28	0.042	11.6	21.8	0.04659	19.4995
14:23	3	11	10	7	22.28	0.039	19.3	22.7	0.046823	22.2188
14:23	4	11	10	7	22.28	0.037	16.2	24.3	0.041899	23.8026
14:23	5	11	10	7	22.28	0.05	31.8	24.2	0.059685	23.9526
14:23	6	11	10	7	22.28	0.037	40.7	24.6	0.041517	24.1497
14:23	7	7	10	7	22.56	0.029	19.6	19.7	0.035389	19.4201
14:23	8	7	10	7	22.56	0.044	27.5	22	0.053842	21.3295
14:23	9	7	10	7	22.56	0.086	29.3	22.4	0.09099	21.8577
14:23	10	7	10	7	22.56	0.074	27.1	23.4	0.078126	22.8033
14:23	11	7	10	7	22.56	0.054	41.6	23.6	0.064325	23.3443
14:23	12	7	10	7	22.56	0.028	57.6	25.1	0.033682	24.6233
14:23	1	11	1	7	22.28	0.036	12.3	20	0.035397	19.829
14:23	2	11	1	7	22.28	0.042	11.6	21.8	0.04659	19.4995
14:23	3	11	1	7	22.28	0.039	19.3	22.7	0.046823	22.2188
14:23	4	11	1	7	22.28	0.037	16.2	24.3	0.041899	23.8026
14:23	5	11	1	7	22.28	0.05	31.8	24.2	0.059685	23.9526
14:23	6	11	1	7	22.28	0.037	40.7	24.6	0.041517	24.1497
14:23	7	7	1	7	22.56	0.029	19.6	19.7	0.035389	19.4201
14:23	8	7	1	7	22.56	0.044	27.5	22	0.053842	21.3295
14:23	9	7	1	7	22.56	0.086	29.3	22.4	0.09099	21.8577
14:23	10	7	1	7	22.F133 56	0.074	27.1	23.4	0.078126	22.8033

14:23	11	7	1	7	22.56	0.054	41.6	23.6	0.064325	23.3443
14:23	12	7	1	7	22.56	0.028	57.6	25.1	0.033682	24.6233
14:32	2	10	10	8	22.27	0.035	56.2	21.1	0.034345	20.8738
14:32	3	10	10	8	22.27	0.085	37.6	22.4	0.088352	20.5582
14:32	4	10	10	8	22.27	0.081	40	23.2	0.088201	22.7028
14:32	5	10	10	8	22.27	0.04	20	24.7	0.045012	24.1855
14:32	6	10	10	8	22.27	0.033	56.8	24.7	0.04354	24.4283
14:32	7	8	10	8	22.8	0.012	37.2	19.8	0.015289	19.508
14:32	8	8	10	8	22.8	0.053	25.5	22	0.057145	21.6306
14:32	9	8	10	8	22.8	0.064	45.3	22.9	0.073634	22.1934
14:32	10	8	10	8	22.8	0.037	79	23.6	0.041255	23.0122
14:32	11	8	10	8	22.8	0.066	39	23.3	0.070934	22.7058
14:32	12	8	10	8	22.8	0.036	60.8	24.7	0.046617	24.4371
14:32	2	10	1	8	22.27	0.035	56.2	21.1	0.040378	20.7537
14:32	3	10	1	8	22.27	0.085	37.6	22.4	0.08698	22.1085
14:32	4	10	1	8	22.27	0.081	40	23.2	0.084467	21.8094
14:32	5	10	1	8	22.27	0.04	20	24.7	0.047808	24.1549
14:32	6	10	1	8	22.27	0.033	56.8	24.7	0.037747	24.1855
14:32	7	8	1	8	22.8	0.012	37.2	19.8	0.023596	19.7669
14:32	8	8	1	8	22.8	0.053	25.5	22	0.058302	21.6354
14:32	9	8	1	8	22.8	0.064	45.3	22.9	0.067116	22.4955
14:32	10	8	1	8	22.8	0.037	79	23.6	0.046915	22.8653
14:32	11	8	1	8	22.8	0.066	39	23.3	0.07069	22.7236
14:32	12	8	1	8	22.8	0.036	60.8	24.7	0.043964	24.0707
14:42	1	9	10	9	21.82	0.15	32.1	19.4	0.15877	19.1719
14:42	2	9	10	9	21.82	0.048	41.8	21.9	0.052812	21.5276
14:42	3	9	10	9	21.82	0.142	31.9	21.1	0.146983	20.8738
14:42	4	9	10	9	21.82	0.082	52	22.4	0.085438	20.5582
14:42	5	9	10	9	21.82	0.028	54.2	24.7	0.035986	24.1549
14:42	6	9	10	9	21.82	0.028	56.8	24.8	0.032558	24.2813
14:42	7	9	8	9	23.17	0.039	41.8	20.8	0.049238	20.7182
14:42	8	9	8	9	23.17	0.052	39.6	21.9	0.057253	21.5387
14:42	9	9	8	9	23.17	0.058	19.5	23.2	0.061677	22.7839
14:42	10	9	8	9	23.17	0.07	14	23.3	0.079572	22.5774
14:42	11	9	8	9	23.17	0.039	30.8	24.5	0.043285	23.8781
14:42	12	9	8	9	23.17	0.046	45.2	25.1	0.052954	24.4607
14:42	7	9	3	9	23.17	0.039	41.8	20.8	0.049568	20.5627
14:42	8	9	3	9	23.17	0.052	39.6	21.9	0.056638	21.5276
14:42	9	9	3	9	23.17	0.058	19.5	23.2	0.058557	22.8683
14:42	10	9	3	9	23.17	0.07	14	23.3	0.073784	22.5794
14:42	11	9	3	9	23.17	0.039	30.8	24.5	0.046823	23.9613
14:42	12	9	3	9	23.17	0.046	45.2	25.1	0.051239	24.5685
14:42	1	9	1	9	21.82	0.15	32.1	19.4	0.154655	19.3864
14:42	2	9	1	9	21.82	0.048	41.8	21.9	0.053057	21.5387
14:42	3	9	1	9	21.82	0.142	31.9	21.1	0.137823	20.7656
14:42	4	9	1	9	21.82	0.082	52	22.4	0.091447	21.7135
14:42	5	9	1	9	21.82	0.028	54.2	24.7	0.03212	24.0705
14:42	6	9	1	9	21.82	0.028	56.8	24.8	0.036772	24.1682
14:52	1	10	8	10	22.72	0.054	42.5	20.6	0.064325	20.364
14:52	2	10	8	10	22.72	0.078	16.2	21.5	0.081507	21.1407
14:52	3	10	8	10	22.72	0.037	18.6	23.3	0.03645	22.9632
14:52	4	10	8	10	22.72	0.046	17.5	24.2	0.050475	22.6756
14:52	5	10	8	10	22.72	0.041	35.6	24.6	0.048793	24.0581
14:52	6	10	8	10	22.72	0.038	52.8	24.7	0.042936	24.1855
14:52	7	8	8	10	23.17	0.036	33.5	20.8	0.046389	20.7182
14:52	8	8	8	10	23.17	0.045	32.6	22	0.04991	21.6354
14:52	9	8	8	10	23.17	0.043	22.4	23.3	0.04808	22.88
14:52	10	8	8	10	23.17	0.06	15.7	23.6	0.069676	22.8653

14:52	11	8	8	10	23.17	0.041	26.6	24.5	0.045315	23.8781
14:52	12	8	8	10	23.17	0.066	43.8	24.9	0.070934	24.2657
14:52	1	10	3	10	22.72	0.054	42.5	20.6	0.064325	20.364
14:52	2	10	3	10	22.72	0.078	16.2	21.5	0.081507	21.1407
14:52	3	10	3	10	22.72	0.037	18.6	23.3	0.03645	22.9632
14:52	4	10	3	10	22.72	0.046	17.5	24.2	0.050475	22.6756
14:52	5	10	3	10	22.72	0.041	35.6	24.6	0.048793	24.0581
14:52	6	10	3	10	22.72	0.038	52.8	24.7	0.042936	24.1855
14:52	7	8	3	10	23.17	0.036	33.5	20.8	0.046389	20.7182
14:52	8	8	3	10	23.17	0.045	32.6	22	0.04991	21.6354
14:52	9	8	3	10	23.17	0.043	22.4	23.3	0.04808	22.88
14:52	10	8	3	10	23.17	0.06	15.7	23.6	0.069676	22.8653
14:52	11	8	3	10	23.17	0.041	26.6	24.5	0.045315	23.8781
14:52	12	8	3	10	23.17	0.066	43.8	24.9	0.070934	24.2657
15:01	1	11	8	11	22.81	0.047	26.9	20.8	0.057439	20.5627
15:01	2	11	8	11	22.81	0.034	24.5	22.4	0.039421	22.0113
15:01	3	11	8	11	22.81	0.038	21.2	23.6	0.037503	23.2482
15:01	4	11	8	11	22.81	0.028	26.7	24.6	0.032994	22.9644
15:01	5	11	8	11	22.81	0.043	22	24.8	0.050764	24.2517
15:01	6	11	8	11	22.81	0.042	25.1	25.4	0.047088	24.8557
15:01	7	7	8	11	23.29	0.04	30.6	21.1	0.050188	21.0036
15:01	8	7	8	11	23.29	0.084	19.7	21.8	0.090824	21.442
15:01	9	7	8	11	23.29	0.044	38.3	23.2	0.048986	22.7839
15:01	10	7	8	11	23.29	0.031	54.4	24	0.040978	23.2493
15:01	11	7	8	11	23.29	0.037	48	24.4	0.041255	23.7819
15:01	12	7	8	11	23.29	0.051	23.4	25.2	0.057449	24.5582
15:01	1	11	3	11	22.81	0.047	26.9	20.8	0.057439	20.5627
15:01	2	11	3	11	22.81	0.034	24.5	22.4	0.039421	22.0113
15:01	3	11	3	11	22.81	0.038	21.2	23.6	0.037503	23.2482
15:01	4	11	3	11	22.81	0.028	26.7	24.6	0.032994	22.9644
15:01	5	11	3	11	22.81	0.043	22	24.8	0.050764	24.2517
15:01	6	11	3	11	22.81	0.042	25.1	25.4	0.047088	24.8557
15:01	7	7	3	11	23.29	0.04	30.6	21.1	0.050188	21.0036
15:01	8	7	3	11	23.29	0.084	19.7	21.8	0.090824	21.442
15:01	9	7	3	11	23.29	0.044	38.3	23.2	0.048986	22.7839
15:01	10	7	3	11	23.29	0.031	54.4	24	0.040978	23.2493
15:01	11	7	3	11	23.29	0.037	48	24.4	0.041255	23.7819
15:01	12	7	3	11	23.29	0.051	23.4	25.2	0.057449	24.5582
15:08	1	12	8	12	22.8	0.045	41.9	21.1	0.055471	20.8607
15:08	2	12	8	12	22.8	0.04	11.3	22.4	0.04516	22.0113
15:08	3	12	8	12	22.8	0.036	17.7	23.1	0.035397	22.7733
15:08	4	12	8	12	22.8	0.034	25.4	24.2	0.038821	22.4832
15:08	5	12	8	12	22.8	0.035	34	24.8	0.042882	24.2517
15:08	6	12	8	12	22.8	0.043	24.8	25.6	0.048125	25.0472
15:08	7	6	8	12	23.33	0.061	16.8	20.8	0.070132	20.7182
15:08	8	6	8	12	23.33	0.055	25.2	22.3	0.060401	21.9255
15:08	9	6	8	12	23.33	0.058	30.5	22.9	0.061677	22.4955
15:08	10	6	8	12	23.33	0.046	24.5	23.9	0.055822	23.1533
15:08	11	6	8	12	23.33	0.036	21.3	24.7	0.04024	24.0705
15:08	12	6	8	12	23.33	0.05	26.6	25.4	0.05655	24.7531
15:08	1	12	3	12	22.8	0.045	41.9	21.1	0.055471	20.8607
15:08	2	12	3	12	22.8	0.04	11.3	22.4	0.04516	22.0113
15:08	3	12	3	12	22.8	0.036	17.7	23.1	0.035397	22.7733
15:08	4	12	3	12	22.8	0.034	25.4	24.2	0.038821	22.4832
15:08	5	12	3	12	22.8	0.035	34	24.8	0.042882	24.2517
15:08	6	12	3	12	22.8	0.043	24.8	25.6	0.048125	25.0472
15:08	7	6	3	12	23.33	0.061	16.8	20.8	0.070132	20.7182
15:08	8	6	3	12	23.33	0.055	25.2	22.3	0.060401	21.9255

15:08	9	6	3	12	23.33	0.058	30.5	22.9	0.061677	22.4955
15:08	10	6	3	12	23.33	0.046	24.5	23.9	0.055822	23.1533
15:08	11	6	3	12	23.33	0.036	21.3	24.7	0.04024	24.0705
15:08	12	6	3	12	23.33	0.05	26.6	25.4	0.05655	24.7531
15:17	1	13	8	13	22.8	0.037	29.8	21.2	0.047601	20.9601
15:17	2	13	8	13	22.8	0.039	12.7	22.4	0.044204	22.0113
15:17	3	13	8	13	22.8	0.035	18.1	23.4	0.034345	23.0582
15:17	4	13	8	13	22.8	0.034	25.2	24.3	0.038821	22.7719
15:17	5	13	8	13	22.8	0.041	27.3	24.6	0.048793	24.0581
15:17	6	13	8	13	22.8	0.045	18	25.8	0.050201	25.2387
15:17	7	5	8	13	23.43	0.053	24.6	20.5	0.062534	20.4328
15:17	8	5	8	13	23.43	0.062	16.4	21.3	0.067744	20.9585
15:17	9	5	8	13	23.43	0.088	11.2	23.3	0.088872	22.88
15:17	10	5	8	13	23.43	0.044	27.9	24.5	0.053842	23.7292
15:17	11	5	8	13	23.43	0.042	16.7	24.6	0.04633	23.9743
15:17	12	5	8	13	23.43	0.061	33.5	25.6	0.066439	24.9481
15:17	1	13	3	13	22.8	0.037	29.8	21.2	0.047601	20.9601
15:17	2	13	3	13	22.8	0.039	12.7	22.4	0.044204	22.0113
15:17	3	13	3	13	22.8	0.035	18.1	23.4	0.034345	23.0582
15:17	4	13	3	13	22.8	0.034	25.2	24.3	0.038821	22.7719
15:17	5	13	3	13	22.8	0.041	27.3	24.6	0.048793	24.0581
15:17	6	13	3	13	22.8	0.045	18	25.8	0.050201	25.2387
15:17	7	5	3	13	23.43	0.053	24.6	20.5	0.062534	20.4328
15:17	8	5	3	13	23.43	0.062	16.4	21.3	0.067744	20.9585
15:17	9	5	3	13	23.43	0.088	11.2	23.3	0.088872	22.88
15:17	10	5	3	13	23.43	0.044	27.9	24.5	0.053842	23.7292
15:17	11	5	3	13	23.43	0.042	16.7	24.6	0.04633	23.9743
15:17	12	5	3	13	23.43	0.061	33.5	25.6	0.066439	24.9481
15:30	1	14	8	14	22.61	0.043	34.9	21.2	0.053503	20.9601
15:30	2	14	8	14	22.61	0.038	7.4	22.4	0.043247	22.0113
15:30	3	14	8	14	22.61	0.041	28.7	22.9	0.040661	22.5833
15:30	4	14	8	14	22.61	0.031	24.2	24.7	0.035907	22.2907
15:30	5	14	8	14	22.61	0.023	31.6	24.9	0.03106	24.3485
15:30	6	14	8	14	23.26	0.04	24.1	25.7	0.045012	25.1429
15:30	7	4	8	14	23.26	0.026	53.8	21.2	0.036892	21.0987
15:30	8	4	8	14	23.26	0.103	11	21.5	0.110757	21.1519
15:30	9	4	8	14	23.26	0.038	32.1	23.7	0.043547	23.2644
15:30	10	4	8	14	23.26	0.035	59.2	24	0.044936	23.2493
15:30	11	4	8	14	23.26	0.041	30.9	24.7	0.045315	24.0705
15:30	12	4	8	14	23.26	0.04	47.7	26	0.04756	25.3381
15:30	1	14	3	14	22.61	0.043	34.9	21.2	0.053503	20.9601
15:30	2	14	3	14	22.61	0.038	7.4	22.4	0.043247	22.0113
15:30	3	14	3	14	22.61	0.041	28.7	22.9	0.040661	22.5833
15:30	4	14	3	14	22.61	0.031	24.2	24.7	0.035907	22.2907
15:30	5	14	3	14	22.61	0.023	31.6	24.9	0.03106	24.3485
15:30	6	14	3	14	23.26	0.04	24.1	25.7	0.045012	25.1429
15:30	7	4	3	14	23.26	0.026	53.8	21.2	0.036892	21.0987
15:30	8	4	3	14	23.26	0.103	11	21.5	0.110757	21.1519
15:30	9	4	3	14	23.26	0.038	32.1	23.7	0.043547	23.2644
15:30	10	4	3	14	23.26	0.035	59.2	24	0.044936	23.2493
15:30	11	4	3	14	23.26	0.041	30.9	24.7	0.045315	24.0705
15:30	12	4	3	14	23.26	0.04	47.7	26	0.04756	25.3381
15:37	1	15	8	15	22.52	0.036	31.4	04:48	0.046617	20.9601
15:37	2	15	8	15	22.52	0.039	8.8	22.4	0.044204	22.0113
15:37	3	15	8	15	22.52	0.033	22.6	23.3	0.032239	22.9632
15:37	4	15	8	15	22.52	0.033	26	24.5	0.03785	22.6756
15:37	5	15	8	15	22.52	0.024	40.9	24.8	0.032045	24.2517
15:37	6	15	8	15	22.52	0.039	24	25.6	0.043974	25.0472

15:37	7	3	8	15	23.14	0.052	22.6	21.2	0.061584	21.0987
15:37	8	3	8	15	23.14	0.07	19.8	21.6	0.076137	21.2486
15:37	9	3	8	15	23.14	0.037	40.9	23.7	0.042641	23.2644
15:37	10	3	8	15	23.14	0.045	48.5	24.4	0.054832	23.6332
15:37	11	3	8	15	23.14	0.045	51.4	24.3	0.049375	23.6857
15:37	12	3	8	15	23.14	0.044	37	25.6	0.051156	24.9481
15:37	1	15	3	15	22.52	0.036	31.4	04:48	0.046617	20.9601
15:37	2	15	3	15	22.52	0.039	8.8	22.4	0.044204	22.0113
15:37	3	15	3	15	22.52	0.033	22.6	23.3	0.032239	22.9632
15:37	4	15	3	15	22.52	0.033	26	24.5	0.03785	22.6756
15:37	5	15	3	15	22.52	0.024	40.9	24.8	0.032045	24.2517
15:37	6	15	3	15	22.52	0.039	24	25.6	0.043974	25.0472
15:37	7	3	3	15	23.14	0.052	22.6	21.2	0.061584	21.0987
15:37	8	3	3	15	23.14	0.07	19.8	21.6	0.076137	21.2486
15:37	9	3	3	15	23.14	0.037	40.9	23.7	0.042641	23.2644
15:37	10	3	3	15	23.14	0.045	48.5	24.4	0.054832	23.6332
15:37	11	3	3	15	23.14	0.045	51.4	24.3	0.049375	23.6857
15:37	12	3	3	15	23.14	0.044	37	25.6	0.051156	24.9481
15:45	1	16	8	16	22.6	0.049	17.3	20.5	0.059406	20.2647
15:45	2	16	8	16	22.6	0.036	11.3	22.5	0.041334	22.1081
15:45	3	16	8	16	22.6	0.032	25.4	23.7	0.031186	23.3431
15:45	4	16	8	16	22.6	0.037	13.2	24.7	0.041734	23.0606
15:45	5	16	8	16	22.6	0.033	39	24.7	0.040912	24.1549
15:45	6	16	8	16	22.6	0.038	20.4	25.6	0.042936	25.0472
15:45	7	2	8	16	23.17	0.048	35.6	21.1	0.057786	21.0036
15:45	8	2	8	16	23.17	0.083	12.7	21.2	0.089775	20.8618
15:45	9	2	8	16	23.17	0.04	37.5	23.5	0.04536	23.0722
15:45	10	2	8	16	23.17	0.036	31.6	24.4	0.045926	23.6332
15:45	11	2	8	16	23.17	0.036	26.7	24.9	0.04024	24.2629
15:45	12	2	8	16	23.17	0.04	29	25.8	0.04756	25.1431
15:45	1	16	3	16	22.6	0.049	17.3	20.5	0.059406	20.2647
15:45	2	16	3	16	22.6	0.036	11.3	22.5	0.041334	22.1081
15:45	3	16	3	16	22.6	0.032	25.4	23.7	0.031186	23.3431
15:45	4	16	3	16	22.6	0.037	13.2	24.7	0.041734	23.0606
15:45	5	16	3	16	22.6	0.033	39	24.7	0.040912	24.1549
15:45	6	16	3	16	22.6	0.038	20.4	25.6	0.042936	25.0472
15:45	7	2	3	16	23.17	0.048	35.6	21.1	0.057786	21.0036
15:45	8	2	3	16	23.17	0.083	12.7	21.2	0.089775	20.8618
15:45	9	2	3	16	23.17	0.04	37.5	23.5	0.04536	23.0722
15:45	10	2	3	16	23.17	0.036	31.6	24.4	0.045926	23.6332
15:45	11	2	3	16	23.17	0.036	26.7	24.9	0.04024	24.2629
15:45	12	2	3	16	23.17	0.04	29	25.8	0.04756	25.1431
15:55	1	17	8	17	22.62	0.044	54.4	20.8	0.054487	20.5627
15:55	2	17	8	17	22.62	0.048	27.5	22	0.052812	21.6244
15:55	3	17	8	17	22.62	0.041	12.8	23.7	0.040661	23.3431
15:55	4	17	8	17	22.62	0.038	25.3	24.7	0.042706	23.0606
15:55	5	17	8	17	22.62	0.042	16.6	24.8	0.049778	24.2517
15:55	6	17	8	17	22.96	0.041	29	25.5	0.04605	24.9515
15:55	7	1	8	17	22.96	0.026	55	21.2	0.036892	21.0987
15:55	8	1	8	17	22.96	0.069	29.7	21.6	0.075088	21.2486
15:55	9	1	8	17	22.96	0.037	12	23.6	0.042641	23.1683
15:55	10	1	8	17	22.96	0.029	25.4	24.5	0.038998	23.7292
15:55	11	1	8	17	22.96	0.037	25.2	24.6	0.041255	23.9743
15:55	12	1	8	17	22.96	0.058	23.4	26.6	0.063742	25.9231
15:55	1	17	3	17	22.62	0.044	54.4	20.8	0.054487	20.5627
15:55	2	17	3	17	22.62	0.048	27.5	22	0.052812	21.6244
15:55	3	17	3	17	22.62	0.041	12.8	23.7	0.040661	23.3431
15:55	4	17	3	17	22.62	0.038	25.3	24.7	0.042706	23.0606

15:55	5	17	3	17	22.62	0.042	16.6	24.8	0.049778	24.2517
15:55	6	17	3	17	22.96	0.041	29	25.5	0.04605	24.9515
15:55	7	1	3	17	22.96	0.026	55	21.2	0.036892	21.0987
15:55	8	1	3	17	22.96	0.069	29.7	21.6	0.075088	21.2486
15:55	9	1	3	17	22.96	0.037	12	23.6	0.042641	23.1683
15:55	10	1	3	17	22.96	0.029	25.4	24.5	0.038998	23.7292
15:55	11	1	3	17	22.96	0.037	25.2	24.6	0.041255	23.9743
15:55	12	1	3	17	22.96	0.058	23.4	26.6	0.063742	25.9231
16:06	1	17	6	18	22.99	0.041	36.2	21.4	0.051536	21.1588
16:06	2	17	6	18	22.99	0.04	5	22.4	0.04516	22.0113
16:06	3	17	6	18	22.99	0.043	16.1	23.7	0.042766	23.3431
16:06	4	17	6	18	22.99	0.048	21.1	24.7	0.052418	23.0606
16:06	5	17	6	18	22.99	0.042	24.5	24.9	0.049778	24.3485
16:06	6	17	6	18	22.99	0.047	25.5	25.2	0.052277	24.6642
16:06	7	1	6	18	23.08	0.062	34.6	21.2	0.071081	21.0987
16:06	8	1	6	18	23.08	0.048	36.8	21.8	0.053057	21.442
16:06	9	1	6	18	23.08	0.032	25.4	23.5	0.038108	23.0722
16:06	10	1	6	18	23.08	0.032	14.1	24.7	0.041967	23.9212
16:06	11	1	6	18	23.08	0.039	11.5	25	0.043285	24.3591
16:06	12	1	6	18	23.08	0.048	24.5	26.6	0.054752	25.9231
16:06	1	17	5	18	22.99	0.041	36.2	21.4	0.051536	21.1588
16:06	2	17	5	18	22.99	0.04	5	22.4	0.04516	22.0113
16:06	3	17	5	18	22.99	0.043	16.1	23.7	0.042766	23.3431
16:06	4	17	5	18	22.99	0.048	21.1	24.7	0.052418	23.0606
16:06	5	17	5	18	22.99	0.042	24.5	24.9	0.049778	24.3485
16:06	6	17	5	18	22.99	0.047	25.5	25.2	0.052277	24.6642
16:06	7	1	5	18	23.08	0.062	34.6	21.2	0.071081	21.0987
16:06	8	1	5	18	23.08	0.048	36.8	21.8	0.053057	21.442
16:06	9	1	5	18	23.08	0.032	25.4	23.5	0.038108	23.0722
16:06	10	1	5	18	23.08	0.032	14.1	24.7	0.041967	23.9212
16:06	11	1	5	18	23.08	0.039	11.5	25	0.043285	24.3591
16:06	12	1	5	18	23.08	0.048	24.5	26.6	0.054752	25.9231
16:13	1	16	6	19	23.12	0.037	39.4	21.5	0.047601	21.2581
16:13	2	16	6	19	23.12	0.04	5	22.5	0.04516	22.1081
16:13	3	16	6	19	23.12	0.041	24.9	23.9	0.040661	23.5331
16:13	4	16	6	19	23.12	0.044	38.7	24.4	0.048533	23.2531
16:13	5	16	6	19	23.12	0.059	41	24.8	0.066527	24.2517
16:13	6	16	6	19	23.12	0.067	42.9	25.1	0.073033	24.5685
16:13	7	2	6	19	23.24	0.055	30.9	21.3	0.064434	21.1939
16:13	8	2	6	19	23.24	0.044	16.3	22.3	0.04886	21.9255
16:13	9	2	6	19	23.24	0.034	36.5	23.6	0.039921	23.1683
16:13	10	2	6	19	23.24	0.033	16	24.7	0.042957	23.9212
16:13	11	2	6	19	23.24	0.046	25.6	24.8	0.05039	24.1667
16:13	12	2	6	19	23.24	0.058	22.3	26.7	0.063742	26.0206
16:13	1	16	5	19	23.12	0.037	39.4	21.5	0.047601	21.2581
16:13	2	16	5	19	23.12	0.04	5	22.5	0.04516	22.1081
16:13	3	16	5	19	23.12	0.041	24.9	23.9	0.040661	23.5331
16:13	4	16	5	19	23.12	0.044	38.7	24.4	0.048533	23.2531
16:13	5	16	5	19	23.12	0.059	41	24.8	0.066527	24.2517
16:13	6	16	5	19	23.12	0.067	42.9	25.1	0.073033	24.5685
16:13	7	2	5	19	23.24	0.055	30.9	21.3	0.064434	21.1939
16:13	8	2	5	19	23.24	0.044	16.3	22.3	0.04886	21.9255
16:13	9	2	5	19	23.24	0.034	36.5	23.6	0.039921	23.1683
16:13	10	2	5	19	23.24	0.033	16	24.7	0.042957	23.9212
16:13	11	2	5	19	23.24	0.046	25.6	24.8	0.05039	24.1667
16:13	12	2	5	19	23.24	0.058	22.3	26.7	0.063742	26.0206
16:21	1	15	6	20	23.05	0.037	38.4	21.5	0.047601	21.2581
16:21	2	15	6	20	23.05	0.038	20.6	22.7	0.043247	22.3015

16:21	3	15	6	20	23.05	0.045	19	24	0.044872	23.6281
16:21	4	15	6	20	23.05	0.062	18.2	24.2	0.066014	23.3494
16:21	5	15	6	20	23.05	0.036	23.7	25.4	0.043867	24.8325
16:21	6	15	6	20	23.05	0.045	29.7	25.9	0.050201	25.3344
16:21	7	3	6	20	23.63	0.072	18.5	21.1	0.080578	21.0036
16:21	8	3	6	20	23.63	0.048	31.9	22	0.053057	21.6354
16:21	9	3	6	20	23.63	0.035	36.3	23.8	0.040828	23.3605
16:21	10	3	6	20	23.63	0.032	30.5	24.8	0.041967	24.0172
16:21	11	3	6	20	23.63	0.066	36	24.6	0.07069	23.9743
16:21	12	3	6	20	23.63	0.056	30.5	27	0.061944	26.3131
16:21	1	15	5	20	23.05	0.037	38.4	21.5	0.047601	21.2581
16:21	2	15	5	20	23.05	0.038	20.6	22.7	0.043247	22.3015
16:21	3	15	5	20	23.05	0.045	19	24	0.044872	23.6281
16:21	4	15	5	20	23.05	0.062	18.2	24.2	0.066014	23.3494
16:21	5	15	5	20	23.05	0.036	23.7	25.4	0.043867	24.8325
16:21	6	15	5	20	23.05	0.045	29.7	25.9	0.050201	25.3344
16:21	7	3	5	20	23.63	0.072	18.5	21.1	0.080578	21.0036
16:21	8	3	5	20	23.63	0.048	31.9	22	0.053057	21.6354
16:21	9	3	5	20	23.63	0.035	36.3	23.8	0.040828	23.3605
16:21	10	3	5	20	23.63	0.032	30.5	24.8	0.041967	24.0172
16:21	11	3	5	20	23.63	0.066	36	24.6	0.07069	23.9743
16:21	12	3	5	20	23.63	0.056	30.5	27	0.061944	26.3131
16:29	1	14	6	21	23.12	0.05	33.2	21.6	0.06039	21.3574
16:29	2	14	6	21	23.12	0.038	17.5	22.8	0.043247	22.3983
16:29	3	14	6	21	23.12	0.065	24.5	23.9	0.065926	23.5331
16:29	4	14	6	21	23.12	0.036	24.3	24.8	0.040763	23.2531
16:29	5	14	6	21	23.12	0.044	25.5	25.2	0.051749	24.6389
16:29	6	14	6	21	23.12	0.041	22.8	26.1	0.04605	25.5259
16:29	7	4	6	21	23.96	0.053	31.1	21.5	0.062534	21.3841
16:29	8	4	6	21	23.96	0.048	25.3	22.2	0.053057	21.8288
16:29	9	4	6	21	23.96	0.048	33.1	23.6	0.052612	23.1683
16:29	10	4	6	21	23.96	0.032	31.8	25.1	0.041967	24.3051
16:29	11	4	6	21	23.96	0.052	35.5	24.9	0.05648	24.2629
16:29	12	4	6	21	23.96	0.05	40.9	27.4	0.05655	26.703
16:29	1	14	5	21	23.12	0.05	33.2	21.6	0.06039	21.3574
16:29	2	14	5	21	23.12	0.038	17.5	22.8	0.043247	22.3983
16:29	3	14	5	21	23.12	0.065	24.5	23.9	0.065926	23.5331
16:29	4	14	5	21	23.12	0.036	24.3	24.8	0.040763	23.2531
16:29	5	14	5	21	23.12	0.044	25.5	25.2	0.051749	24.6389
16:29	6	14	5	21	23.12	0.041	22.8	26.1	0.04605	25.5259
16:29	7	4	5	21	23.96	0.053	31.1	21.5	0.062534	21.3841
16:29	8	4	5	21	23.96	0.048	25.3	22.2	0.053057	21.8288
16:29	9	4	5	21	23.96	0.048	33.1	23.6	0.052612	23.1683
16:29	10	4	5	21	23.96	0.032	31.8	25.1	0.041967	24.3051
16:29	11	4	5	21	23.96	0.052	35.5	24.9	0.05648	24.2629
16:29	12	4	5	21	23.96	0.05	40.9	27.4	0.05655	26.703
16:36	1	13	6	22	23.25	0.032	50.8	21.6	0.042682	21.3574
16:36	2	13	6	22	23.25	0.036	25.9	22.4	0.041334	22.0113
16:36	3	13	6	22	23.25	0.061	26.6	24.2	0.061715	23.818
16:36	4	13	6	22	23.25	0.036	12.3	25.2	0.040763	23.5419
16:36	5	13	6	22	23.25	0.04	16.4	25.1	0.047808	24.5421
16:36	6	13	6	22	23.25	0.042	22.1	26.4	0.047088	25.8131
16:36	7	5	6	22	24	0.062	31.8	21.5	0.071081	21.3841
16:36	8	5	6	22	24	0.062	28.7	21.8	0.067744	21.442
16:36	9	5	6	22	24	0.045	25.4	23.6	0.049893	23.1683
16:36	10	5	6	22	24	0.032	23.4	25.2	0.041967	24.4011
16:36	11	5	6	22	24	0.057	32	25	0.061555	24.3591
16:36	12	5	6	22	24	0.052	29.7	27.6	0.058348	26.898

16:36	1	13	5	22	23.25	0.032	50.8	21.6	0.042682	21.3574
16:36	2	13	5	22	23.25	0.036	25.9	22.4	0.041334	22.0113
16:36	3	13	5	22	23.25	0.061	26.6	24.2	0.061715	23.818
16:36	4	13	5	22	23.25	0.036	12.3	25.2	0.040763	23.5419
16:36	5	13	5	22	23.25	0.04	16.4	25.1	0.047808	24.5421
16:36	6	13	5	22	23.25	0.042	22.1	26.4	0.047088	25.8131
16:36	7	5	5	22	24	0.062	31.8	21.5	0.071081	21.3841
16:36	8	5	5	22	24	0.062	28.7	21.8	0.067744	21.442
16:36	9	5	5	22	24	0.045	25.4	23.6	0.049893	23.1683
16:36	10	5	5	22	24	0.032	23.4	25.2	0.041967	24.4011
16:36	11	5	5	22	24	0.057	32	25	0.061555	24.3591
16:36	12	5	5	22	24	0.052	29.7	27.6	0.058348	26.898
16:44	1	12	6	23	23.38	0.041	41.3	21.9	0.051536	21.6555
16:44	2	12	6	23	23.38	0.041	36.8	22	0.046117	21.6244
16:44	3	12	6	23	23.38	0.101	15.9	22.9	0.103823	22.5833
16:44	4	12	6	23	23.38	0.032	25.2	25.2	0.036878	22.2907
16:44	5	12	6	23	23.38	0.042	21.2	25.5	0.049778	24.9293
16:44	6	12	6	23	23.38	0.065	29.5	25.6	0.070957	25.0472
16:44	7	6	6	23	24.08	0.098	17.4	21.3	0.105271	21.1939
16:44	8	6	6	23	24.08	0.087	20.6	21.5	0.093972	21.1519
16:44	9	6	6	23	24.08	0.049	37.3	23.6	0.053519	23.1683
16:44	10	6	6	23	24.08	0.037	24	25.3	0.046915	24.4971
16:44	11	6	6	23	24.08	0.058	33.6	25.1	0.06257	24.4554
16:44	12	6	6	23	24.08	0.057	25.7	27.8	0.062843	27.093
16:44	1	12	5	23	23.38	0.041	41.3	21.9	0.051536	21.6555
16:44	2	12	5	23	23.38	0.041	36.8	22	0.046117	21.6244
16:44	3	12	5	23	23.38	0.101	15.9	22.9	0.103823	22.5833
16:44	4	12	5	23	23.38	0.032	25.2	25.2	0.036878	22.2907
16:44	5	12	5	23	23.38	0.042	21.2	25.5	0.049778	24.9293
16:44	6	12	5	23	23.38	0.065	29.5	25.6	0.070957	25.0472
16:44	7	6	5	23	24.08	0.098	17.4	21.3	0.105271	21.1939
16:44	8	6	5	23	24.08	0.087	20.6	21.5	0.093972	21.1519
16:44	9	6	5	23	24.08	0.049	37.3	23.6	0.053519	23.1683
16:44	10	6	5	23	24.08	0.037	24	25.3	0.046915	24.4971
16:44	11	6	5	23	24.08	0.058	33.6	25.1	0.06257	24.4554
16:44	12	6	5	23	24.08	0.057	25.7	27.8	0.062843	27.093
16:52	1	11	6	24	23.36	0.067	20.6	21.7	0.077115	21.4568
16:52	2	11	6	24	23.36	0.06	29.3	21.9	0.06429	21.5276
16:52	3	11	6	24	23.36	0.103	12.3	22.8	0.105928	22.4884
16:52	4	11	6	24	23.36	0.037	36.6	25	0.041734	22.1944
16:52	5	11	6	24	23.36	0.04	16.5	25.5	0.047808	24.9293
16:52	6	11	6	24	23.36	0.08	31.4	25.5	0.086524	24.9515
16:52	7	7	6	24	23.95	0.094	27.5	21.2	0.101472	21.0987
16:52	8	7	6	24	23.95	0.039	44.5	22.4	0.043615	22.0222
16:52	9	7	6	24	23.95	0.055	37.9	23.7	0.058958	23.2644
16:52	10	7	6	24	23.95	0.032	55.6	25	0.041967	24.2092
16:52	11	7	6	24	23.95	0.049	18.2	25.4	0.053435	24.744
16:52	12	7	6	24	23.95	0.075	31.2	27.7	0.079025	26.9955
16:52	1	11	5	24	23.36	0.067	20.6	21.7	0.077115	21.4568
16:52	2	11	5	24	23.36	0.06	29.3	21.9	0.06429	21.5276
16:52	3	11	5	24	23.36	0.103	12.3	22.8	0.105928	22.4884
16:52	4	11	5	24	23.36	0.037	36.6	25	0.041734	22.1944
16:52	5	11	5	24	23.36	0.04	16.5	25.5	0.047808	24.9293
16:52	6	11	5	24	23.36	0.08	31.4	25.5	0.086524	24.9515
16:52	7	7	5	24	23.95	0.094	27.5	21.2	0.101472	21.0987
16:52	8	7	5	24	23.95	0.039	44.5	22.4	0.043615	22.0222
16:52	9	7	5	24	23.95	0.055	37.9	23.7	0.058958	23.2644
16:52	10	7	5	24	23.95	0.032	55.6	25	0.041967	24.2092

16:52	11	7	5	24	23.95	0.049	18.2	25.4	0.053435	24.744
16:52	12	7	5	24	23.95	0.075	31.2	27.7	0.079025	26.9955
16:58	1	10	6	25	23.5	0.099	20.6	21.3	0.108596	21.0594
16:58	2	10	6	25	23.5	0.07	37.1	22.3	0.073855	21.9146
16:58	3	10	6	25	23.5	0.095	27.2	22.9	0.097507	22.5833
16:58	4	10	6	25	23.5	0.036	31	25.5	0.040763	22.2907
16:58	5	10	6	25	23.5	0.035	31.1	25.6	0.042882	25.0261
16:58	6	10	6	25	23.5	0.075	28.7	25.7	0.081335	25.1429
16:58	7	8	6	25	23.95	0.16	10	20.7	0.164152	20.6231
16:58	8	8	6	25	23.95	0.09	20.8	22	0.097119	21.6354
16:58	9	8	6	25	23.95	0.142	28.7	24	0.137823	23.5527
16:58	10	8	6	25	23.95	0.039	47.2	25	0.048894	24.2092
16:58	11	8	6	25	23.95	0.046	26.6	25.4	0.05039	24.744
16:58	12	8	6	25	23.95	0.08	30.7	27.6	0.08352	26.898
16:58	1	10	5	25	23.5	0.099	20.6	21.3	0.108596	21.0594
16:58	2	10	5	25	23.5	0.07	37.1	22.3	0.073855	21.9146
16:58	3	10	5	25	23.5	0.095	27.2	22.9	0.097507	22.5833
16:58	4	10	5	25	23.5	0.036	31	25.5	0.040763	22.2907
16:58	5	10	5	25	23.5	0.035	31.1	25.6	0.042882	25.0261
16:58	6	10	5	25	23.5	0.075	28.7	25.7	0.081335	25.1429
16:58	7	8	5	25	23.95	0.16	10	20.7	0.164152	20.6231
16:58	8	8	5	25	23.95	0.09	20.8	22	0.097119	21.6354
16:58	9	8	5	25	23.95	0.142	28.7	24	0.137823	23.5527
16:58	10	8	5	25	23.95	0.039	47.2	25	0.048894	24.2092
16:58	11	8	5	25	23.95	0.046	26.6	25.4	0.05039	24.744
16:58	12	8	5	25	23.95	0.08	30.7	27.6	0.08352	26.898
17:04	7	9	7	26	24.43	0.059	28.4	21.5	0.069244	21.2581
17:04	8	9	7	26	24.43	0.047	24.3	23	0.051856	22.5918
17:04	9	9	7	26	24.43	0.07	11.5	23.9	0.071189	23.5331
17:04	10	9	7	26	24.43	0.036	51.8	25.1	0.040763	23.2531
17:04	11	9	7	26	24.43	0.043	29	25.2	0.050764	24.6389
17:04	12	9	7	26	24.43	0.01	25.8	27.5	0.013878	26.8663
17:04	1	9	6	26	24.23	0.124	14.5	21.2	0.129963	21.0987
17:04	2	9	6	26	24.23	0.151	21.2	22	0.161114	21.6354
17:04	3	9	6	26	24.23	0.179	20	23.7	0.171364	23.2644
17:04	4	9	6	26	24.23	0.045	33.5	25.5	0.054832	24.6891
17:04	5	9	6	26	24.23	0.046	35.6	25.4	0.05039	24.744
17:04	6	9	6	26	24.23	0.065	30.7	25.7	0.070035	25.0456
17:04	1	9	5	26	24.23	0.124	14.5	21.2	0.133191	20.9601
17:04	2	9	5	26	24.23	0.151	21.2	22	0.151332	21.6244
17:04	3	9	5	26	24.23	0.179	20	23.7	0.185933	23.3431
17:04	4	9	5	26	24.23	0.045	33.5	25.5	0.049504	23.0606
17:04	5	9	5	26	24.23	0.046	35.6	25.4	0.053719	24.8325
17:04	6	9	5	26	24.23	0.065	30.7	25.7	0.070957	25.1429
17:04	7	9	4	26	24.43	0.059	28.4	21.5	0.068232	21.3841
17:04	8	9	4	26	24.43	0.047	24.3	23	0.052008	22.6025
17:04	9	9	4	26	24.43	0.07	11.5	23.9	0.072555	23.4566
17:04	10	9	4	26	24.43	0.036	51.8	25.1	0.045926	24.3051
17:04	11	9	4	26	24.43	0.043	29	25.2	0.047345	24.5516
17:04	12	9	4	26	24.43	0.01	25.8	27.5	0.02059	26.8005
17:12	1	10	7	27	24	0.088	15	22	0.097774	21.7548
17:12	2	10	7	27	24	0.079	24.7	22.1	0.082464	21.7211
17:12	3	10	7	27	24	0.051	28	24	0.051188	23.6281
17:12	4	10	7	27	24	0.049	14.3	25.4	0.053389	23.3494
17:12	5	10	7	27	24	0.035	35	25.6	0.042882	25.0261
17:12	6	10	7	27	24	0.072	41.3	25.5	0.078222	24.9515
17:12	7	8	7	27	24.58	0.064	22.7	22	0.072981	21.8598
17:12	8	8	7	27	24.58	0.075	31	22	0.081383	21.6354

17:12	9	8	7	27	24.58	0.082	13	23.3	0.083433	22.88
17:12	10	8	7	27	24.58	0.034	26.6	25.2	0.043946	24.4011
17:12	11	8	7	27	24.58	0.044	21.7	25.2	0.04836	24.5516
17:12	12	8	7	27	24.58	0.01	25.5	27.5	0.02059	26.8005
17:12	1	10	4	27	24	0.088	15	22	0.097774	21.7548
17:12	2	10	4	27	24	0.079	24.7	22.1	0.082464	21.7211
17:12	3	10	4	27	24	0.051	28	24	0.051188	23.6281
17:12	4	10	4	27	24	0.049	14.3	25.4	0.053389	23.3494
17:12	5	10	4	27	24	0.035	35	25.6	0.042882	25.0261
17:12	6	10	4	27	24	0.072	41.3	25.5	0.078222	24.9515
17:12	7	8	4	27	24.58	0.064	22.7	22	0.072981	21.8598
17:12	8	8	4	27	24.58	0.075	31	22	0.081383	21.6354
17:12	9	8	4	27	24.58	0.082	13	23.3	0.083433	22.88
17:12	10	8	4	27	24.58	0.034	26.6	25.2	0.043946	24.4011
17:12	11	8	4	27	24.58	0.044	21.7	25.2	0.04836	24.5516
17:12	12	8	4	27	24.58	0.01	25.5	27.5	0.02059	26.8005
17:19	1	11	7	28	23.8	0.06	25.8	21.8	0.070228	21.5561
17:19	2	11	7	28	23.8	0.05	36.5	22.4	0.054725	22.0113
17:19	3	11	7	28	23.8	0.056	28.2	23.2	0.056451	22.8683
17:19	4	11	7	28	23.8	0.038	33.1	25.5	0.042706	22.5794
17:19	5	11	7	28	23.8	0.035	64	25.1	0.042882	24.5421
17:19	6	11	7	28	23.8	0.05	43.8	25.6	0.05539	25.0472
17:19	7	7	7	28	24.4	0.036	31.9	22.4	0.046389	22.2403
17:19	8	7	7	28	24.4	0.039	53.2	22.6	0.043615	22.2156
17:19	9	7	7	28	24.4	0.057	28.1	24.7	0.060771	24.2255
17:19	10	7	7	28	24.4	0.031	37.7	25.4	0.040978	24.5931
17:19	11	7	7	28	24.4	0.05	36.1	25.2	0.05445	24.5516
17:19	12	7	7	28	24.4	0.008	26.6	27.6	0.018792	26.898
17:19	1	11	4	28	23.8	0.06	25.8	21.8	0.070228	21.5561
17:19	2	11	4	28	23.8	0.05	36.5	22.4	0.054725	22.0113
17:19	3	11	4	28	23.8	0.056	28.2	23.2	0.056451	22.8683
17:19	4	11	4	28	23.8	0.038	33.1	25.5	0.042706	22.5794
17:19	5	11	4	28	23.8	0.035	64	25.1	0.042882	24.5421
17:19	6	11	4	28	23.8	0.05	43.8	25.6	0.05539	25.0472
17:19	7	7	4	28	24.4	0.036	31.9	22.4	0.046389	22.2403
17:19	8	7	4	28	24.4	0.039	53.2	22.6	0.043615	22.2156
17:19	9	7	4	28	24.4	0.057	28.1	24.7	0.060771	24.2255
17:19	10	7	4	28	24.4	0.031	37.7	25.4	0.040978	24.5931
17:19	11	7	4	28	24.4	0.05	36.1	25.2	0.05445	24.5516
17:19	12	7	4	28	24.4	0.008	26.6	27.6	0.018792	26.898
17:26	1	12	7	29	23.68	0.074	19.7	21.7	0.084001	21.4568
17:26	2	12	7	29	23.68	0.077	22.1	22.2	0.080551	21.8178
17:26	3	12	7	29	23.68	0.052	40.9	23.3	0.05224	22.9632
17:26	4	12	7	29	23.68	0.041	27	25.3	0.045619	22.6756
17:26	5	12	7	29	23.68	0.037	45	25.6	0.044852	25.0261
17:26	6	12	7	29	23.68	0.056	52	26	0.061617	25.4302
17:26	7	6	7	29	24.27	0.034	31.5	22.5	0.04449	22.3354
17:26	8	6	7	29	24.27	0.03	54	22.4	0.034173	22.0222
17:26	9	6	7	29	24.27	0.071	23.2	24.1	0.073462	23.6488
17:26	10	6	7	29	24.27	0.042	31.7	25.3	0.051863	24.4971
17:26	11	6	7	29	24.27	0.043	13.9	25.6	0.047345	24.9364
17:26	12	6	7	29	24.27	0.009	17	27.7	0.019691	26.9955
17:26	1	12	4	29	23.68	0.074	19.7	21.7	0.084001	21.4568
17:26	2	12	4	29	23.68	0.077	22.1	22.2	0.080551	21.8178
17:26	3	12	4	29	23.68	0.052	40.9	23.3	0.05224	22.9632
17:26	4	12	4	29	23.68	0.041	27	25.3	0.045619	22.6756
17:26	5	12	4	29	23.68	0.037	45	25.6	0.044852	25.0261
17:26	6	12	4	29	23.68	0.056	52	26	0.061617	25.4302

17:26	7	6	4	29	24.27	0.034	31.5	22.5	0.04449	22.3354
17:26	8	6	4	29	24.27	0.03	54	22.4	0.034173	22.0222
17:26	9	6	4	29	24.27	0.071	23.2	24.1	0.073462	23.6488
17:26	10	6	4	29	24.27	0.042	31.7	25.3	0.051863	24.4971
17:26	11	6	4	29	24.27	0.043	13.9	25.6	0.047345	24.9364
17:26	12	6	4	29	24.27	0.009	17	27.7	0.019691	26.9955
17:32	1	13	7	30	23.63	0.073	19.8	21.6	0.083017	21.3574
17:32	2	13	7	30	23.63	0.059	31.7	22.4	0.063334	22.0113
17:32	3	13	7	30	23.63	0.048	33.8	24.2	0.04803	23.818
17:32	4	13	7	30	23.63	0.037	20.3	25.6	0.041734	23.5419
17:32	5	13	7	30	23.63	0.043	29.6	25.5	0.050764	24.9293
17:32	6	13	7	30	23.63	0.041	30.4	26.1	0.04605	25.5259
17:32	7	5	7	30	24.32	0.033	46.2	22	0.04354	21.8598
17:32	8	5	7	30	24.32	0.042	45	22.9	0.046762	22.5058
17:32	9	5	7	30	24.32	0.074	14.3	25.4	0.076181	24.8982
17:32	10	5	7	30	24.32	0.037	23.2	25.4	0.046915	24.5931
17:32	11	5	7	30	24.32	0.047	21	25.6	0.051405	24.9364
17:32	12	5	7	30	24.32	0.01	19	27.8	0.02059	27.093
17:32	1	13	4	30	23.63	0.073	19.8	21.6	0.083017	21.3574
17:32	2	13	4	30	23.63	0.059	31.7	22.4	0.063334	22.0113
17:32	3	13	4	30	23.63	0.048	33.8	24.2	0.04803	23.818
17:32	4	13	4	30	23.63	0.037	20.3	25.6	0.041734	23.5419
17:32	5	13	4	30	23.63	0.043	29.6	25.5	0.050764	24.9293
17:32	6	13	4	30	23.63	0.041	30.4	26.1	0.04605	25.5259
17:32	7	5	4	30	24.32	0.033	46.2	22	0.04354	21.8598
17:32	8	5	4	30	24.32	0.042	45	22.9	0.046762	22.5058
17:32	9	5	4	30	24.32	0.074	14.3	25.4	0.076181	24.8982
17:32	10	5	4	30	24.32	0.037	23.2	25.4	0.046915	24.5931
17:32	11	5	4	30	24.32	0.047	21	25.6	0.051405	24.9364
17:32	12	5	4	30	24.32	0.01	19	27.8	0.02059	27.093
17:38	1	14	7	31	23.6	0.046	44.4	22	0.056455	21.7548
17:38	2	14	7	31	23.6	0.037	18.8	23.2	0.042291	22.7852
17:38	3	14	7	31	23.6	0.04	32.1	24.3	0.039608	23.913
17:38	4	14	7	31	23.6	0.047	23.6	24.8	0.051446	23.6381
17:38	5	14	7	31	23.6	0.042	15.1	25.6	0.049778	25.0261
17:38	6	14	7	31	23.6	0.047	47.2	26.1	0.052277	25.5259
17:38	7	4	7	31	24.3	0.034	26.7	22.4	0.04449	22.2403
17:38	8	4	7	31	24.3	0.038	50.3	22.8	0.042566	22.4091
17:38	9	4	7	31	24.3	0.071	12.6	23.9	0.073462	23.4566
17:38	10	4	7	31	24.3	0.034	27.9	25.5	0.043946	24.6891
17:38	11	4	7	31	24.3	0.032	43.8	25.6	0.03618	24.9364
17:38	12	4	7	31	24.3	0.011	18	27.7	0.021489	26.9955
17:38	1	14	4	31	23.6	0.046	44.4	22	0.056455	21.7548
17:38	2	14	4	31	23.6	0.037	18.8	23.2	0.042291	22.7852
17:38	3	14	4	31	23.6	0.04	32.1	24.3	0.039608	23.913
17:38	4	14	4	31	23.6	0.047	23.6	24.8	0.051446	23.6381
17:38	5	14	4	31	23.6	0.042	15.1	25.6	0.049778	25.0261
17:38	6	14	4	31	23.6	0.047	47.2	26.1	0.052277	25.5259
17:38	7	4	4	31	24.3	0.034	26.7	22.4	0.04449	22.2403
17:38	8	4	4	31	24.3	0.038	50.3	22.8	0.042566	22.4091
17:38	9	4	4	31	24.3	0.071	12.6	23.9	0.073462	23.4566
17:38	10	4	4	31	24.3	0.034	27.9	25.5	0.043946	24.6891
17:38	11	4	4	31	24.3	0.032	43.8	25.6	0.03618	24.9364
17:38	12	4	4	31	24.3	0.011	18	27.7	0.021489	26.9955
17:45	1	15	7	32	23.56	0.059	45.2	21.5	0.069244	21.2581
17:45	2	15	7	32	23.56	0.035	19	23.1	0.040378	22.6885
17:45	3	15	7	32	23.56	0.039	37.8	24	0.038555	23.6281
17:45	4	15	7	32	23.56	0.053	25.8	24.9	0.057274	23.3494

17:45	5	15	7	32	23.56	0.042	23.4	25.6	0.049778	25.0261
17:45	6	15	7	32	23.56	0.063	43.3	25.7	0.068881	25.1429
17:45	7	3	7	32	24.19	0.034	37.7	22	0.04449	21.8598
17:45	8	3	7	32	24.19	0.036	33.5	23.2	0.040468	22.7959
17:45	9	3	7	32	24.19	0.065	34.2	23.6	0.068023	23.1683
17:45	10	3	7	32	24.19	0.039	17.8	25.4	0.048894	24.5931
17:45	11	3	7	32	24.19	0.04	37.1	25.6	0.0443	24.9364
17:45	12	3	7	32	24.19	0.011	21.8	27.6	0.021489	26.898
17:45	1	15	4	32	23.56	0.059	45.2	21.5	0.069244	21.2581
17:45	2	15	4	32	23.56	0.035	19	23.1	0.040378	22.6885
17:45	3	15	4	32	23.56	0.039	37.8	24	0.038555	23.6281
17:45	4	15	4	32	23.56	0.053	25.8	24.9	0.057274	23.3494
17:45	5	15	4	32	23.56	0.042	23.4	25.6	0.049778	25.0261
17:45	6	15	4	32	23.56	0.063	43.3	25.7	0.068881	25.1429
17:45	7	3	4	32	24.19	0.034	37.7	22	0.04449	21.8598
17:45	8	3	4	32	24.19	0.036	33.5	23.2	0.040468	22.7959
17:45	9	3	4	32	24.19	0.065	34.2	23.6	0.068023	23.1683
17:45	10	3	4	32	24.19	0.039	17.8	25.4	0.048894	24.5931
17:45	11	3	4	32	24.19	0.04	37.1	25.6	0.0443	24.9364
17:45	12	3	4	32	24.19	0.011	21.8	27.6	0.021489	26.898
17:55	1	16	7	33	23.67	0.074	24.9	21.6	0.084001	21.3574
17:55	2	16	7	33	23.67	0.056	29.6	22.9	0.060464	22.495
17:55	3	16	7	33	23.67	0.056	34.8	24.2	0.056451	23.818
17:55	4	16	7	33	23.67	0.078	27.1	24.8	0.081554	23.5419
17:55	5	16	7	33	23.67	0.053	53.8	25.1	0.060616	24.5421
17:55	6	16	7	33	23.67	0.038	41.9	26	0.042936	25.4302
17:55	7	2	7	33	23.99	0.041	29.9	22	0.051138	21.8598
17:55	8	2	7	33	23.99	0.043	14.9	22.9	0.047811	22.5058
17:55	9	2	7	33	23.99	0.05	35.6	23.9	0.054425	23.4566
17:55	10	2	7	33	23.99	0.036	9.7	25.3	0.045926	24.4971
17:55	11	2	7	33	23.99	0.043	20.2	25.6	0.047345	24.9364
17:55	12	2	7	33	23.99	0.009	17.3	27.6	0.019691	26.898
17:55	1	16	4	33	23.67	0.074	24.9	21.6	0.084001	21.3574
17:55	2	16	4	33	23.67	0.056	29.6	22.9	0.060464	22.495
17:55	3	16	4	33	23.67	0.056	34.8	24.2	0.056451	23.818
17:55	4	16	4	33	23.67	0.078	27.1	24.8	0.081554	23.5419
17:55	5	16	4	33	23.67	0.053	53.8	25.1	0.060616	24.5421
17:55	6	16	4	33	23.67	0.038	41.9	26	0.042936	25.4302
17:55	7	2	4	33	23.99	0.041	29.9	22	0.051138	21.8598
17:55	8	2	4	33	23.99	0.043	14.9	22.9	0.047811	22.5058
17:55	9	2	4	33	23.99	0.05	35.6	23.9	0.054425	23.4566
17:55	10	2	4	33	23.99	0.036	9.7	25.3	0.045926	24.4971
17:55	11	2	4	33	23.99	0.043	20.2	25.6	0.047345	24.9364
17:55	12	2	4	33	23.99	0.009	17.3	27.6	0.019691	26.898
18:01	1	17	7	34	23.64	0.048	30.9	21.7	0.058422	21.4568
18:01	2	17	7	34	23.64	0.037	23.6	22.8	0.042291	22.3983
18:01	3	17	7	34	23.64	0.044	10.1	24.4	0.043819	24.008
18:01	4	17	7	34	23.64	0.036	30.9	25.4	0.040763	23.7344
18:01	5	17	7	34	23.64	0.034	52	25.6	0.041897	25.0261
18:01	6	17	7	34	23.64	0.033	61.8	25.8	0.037747	25.2387
18:01	7	1	7	34	23.8	0.045	39.9	21.9	0.054937	21.7646
18:01	8	1	7	34	23.8	0.043	11.5	22.9	0.048231	22.5058
18:01	9	1	7	34	23.8	0.039	14.6	24.4	0.044454	23.9371
18:01	10	1	7	34	23.8	0.041	30	25.2	0.050874	24.4011
18:01	11	1	7	34	23.8	0.026	59	25.5	0.03009	24.8402
18:01	12	1	7	34	23.8	0.01	14.8	27.6	0.02059	26.898
18:01	1	17	4	34	23.64	0.048	30.9	21.7	0.058422	21.4568
18:01	2	17	4	34	23.64	0.037	23.6	22.8	0.042291	22.3983

18:01	3	17	4	34	23.64	0.044	10.1	24.4	0.043819	24.008
18:01	4	17	4	34	23.64	0.036	30.9	25.4	0.040763	23.7344
18:01	5	17	4	34	23.64	0.034	52	25.6	0.041897	25.0261
18:01	6	17	4	34	23.64	0.033	61.8	25.8	0.037747	25.2387
18:01	7	1	4	34	23.8	0.045	39.9	21.9	0.054937	21.7646
18:01	8	1	4	34	23.8	0.043	11.5	22.9	0.048231	22.5058
18:01	9	1	4	34	23.8	0.039	14.6	24.4	0.044454	23.9371
18:01	10	1	4	34	23.8	0.041	30	25.2	0.050874	24.4011
18:01	11	1	4	34	23.8	0.026	59	25.5	0.03009	24.8402
18:01	12	1	4	34	23.8	0.01	14.8	27.6	0.02059	26.898
18:08	1	17	9	35	23.37	0.048	53.2	21.7	0.058422	21.4568
18:08	2	17	9	35	23.37	0.051	26.8	22.3	0.055682	21.9146
18:08	3	17	9	35	23.37	0.036	20	24.2	0.035397	23.818
18:08	4	17	9	35	23.37	0.036	25.2	25.4	0.040763	23.5419
18:08	5	17	9	35	23.37	0.038	18.8	25.6	0.045838	25.0261
18:08	6	17	9	35	23.37	0.044	26.4	26	0.049163	25.4302
18:08	7	1	9	35	23.62	0.106	26.1	20.8	0.112868	20.7182
18:08	8	1	9	35	23.62	0.06	22.7	20.8	0.065646	20.475
18:08	9	1	9	35	23.62	0.051	25.5	22.5	0.055332	22.1111
18:08	10	1	9	35	23.62	0.032	19.7	23.9	0.041967	23.1533
18:08	11	1	9	35	23.62	0.041	34.5	25.6	0.045315	24.9364
18:08	12	1	9	35	23.62	0.01	16.4	27.6	0.02059	26.898
18:08	1	17	2	35	23.37	0.048	53.2	21.7	0.058422	21.4568
18:08	2	17	2	35	23.37	0.051	26.8	22.3	0.055682	21.9146
18:08	3	17	2	35	23.37	0.036	20	24.2	0.035397	23.818
18:08	4	17	2	35	23.37	0.036	25.2	25.4	0.040763	23.5419
18:08	5	17	2	35	23.37	0.038	18.8	25.6	0.045838	25.0261
18:08	6	17	2	35	23.37	0.044	26.4	26	0.049163	25.4302
18:08	7	1	2	35	23.62	0.106	26.1	20.8	0.112868	20.7182
18:08	8	1	2	35	23.62	0.06	22.7	20.8	0.065646	20.475
18:08	9	1	2	35	23.62	0.051	25.5	22.5	0.055332	22.1111
18:08	10	1	2	35	23.62	0.032	19.7	23.9	0.041967	23.1533
18:08	11	1	2	35	23.62	0.041	34.5	25.6	0.045315	24.9364
18:08	12	1	2	35	23.62	0.01	16.4	27.6	0.02059	26.898
18:14	1	16	9	36	23.38	0.034	37.3	22	0.044649	21.7548
18:14	2	16	9	36	23.38	0.036	22.6	23.2	0.041334	22.7852
18:14	3	16	9	36	23.38	0.042	19.6	24.1	0.041713	23.7231
18:14	4	16	9	36	23.38	0.033	32.6	25.4	0.03785	23.4456
18:14	5	16	9	36	23.38	0.037	18.1	25.7	0.044852	25.1229
18:14	6	16	9	36	23.38	0.043	20.4	26.2	0.048125	25.6216
18:14	7	2	9	36	23.74	0.037	19.4	22	0.047339	21.8598
18:14	8	2	9	36	23.74	0.043	33.2	22.9	0.047811	22.5058
18:14	9	2	9	36	23.74	0.037	32.6	24.2	0.042641	23.7449
18:14	10	2	9	36	23.74	0.036	21.6	25.5	0.045926	24.6891
18:14	11	2	9	36	23.74	0.033	46.5	25.6	0.037195	24.9364
18:14	12	2	9	36	23.74	0.01	18.3	27.6	0.02059	26.898
18:14	1	16	2	36	23.38	0.034	37.3	22	0.044649	21.7548
18:14	2	16	2	36	23.38	0.036	22.6	23.2	0.041334	22.7852
18:14	3	16	2	36	23.38	0.042	19.6	24.1	0.041713	23.7231
18:14	4	16	2	36	23.38	0.033	32.6	25.4	0.03785	23.4456
18:14	5	16	2	36	23.38	0.037	18.1	25.7	0.044852	25.1229
18:14	6	16	2	36	23.38	0.043	20.4	26.2	0.048125	25.6216
18:14	7	2	2	36	23.74	0.037	19.4	22	0.047339	21.8598
18:14	8	2	2	36	23.74	0.043	33.2	22.9	0.047811	22.5058
18:14	9	2	2	36	23.74	0.037	32.6	24.2	0.042641	23.7449
18:14	10	2	2	36	23.74	0.036	21.6	25.5	0.045926	24.6891
18:14	11	2	2	36	23.74	0.033	46.5	25.6	0.037195	24.9364
18:14	12	2	2	36	23.74	0.01	18.3	27.6	0.02059	26.898

18:21	1	15	9	37	23.4	0.031	38.5	22.2	0.041698	21.9535
18:21	2	15	9	37	23.4	0.036	23.5	23.2	0.041334	22.7852
18:21	3	15	9	37	23.4	0.038	20.4	24	0.037503	23.6281
18:21	4	15	9	37	23.4	0.045	32	25.6	0.049504	23.3494
18:21	5	15	9	37	23.4	0.036	22.3	25.8	0.043867	25.2197
18:21	6	15	9	37	23.4	0.035	22.1	26.6	0.039823	26.0046
18:21	7	3	9	37	24.16	0.038	19	22	0.048289	21.8598
18:21	8	3	9	37	24.16	0.047	6.1	23.2	0.052008	22.7959
18:21	9	3	9	37	24.16	0.044	10.1	24.4	0.048986	23.9371
18:21	10	3	9	37	24.16	0.036	19.2	25.5	0.045926	24.6891
18:21	11	3	9	37	24.16	0.036	38.2	25.8	0.04024	25.1288
18:21	12	3	9	37	24.16	0.01	17.3	27.8	0.02059	27.093
18:21	1	15	2	37	23.4	0.031	38.5	22.2	0.041698	21.9535
18:21	2	15	2	37	23.4	0.036	23.5	23.2	0.041334	22.7852
18:21	3	15	2	37	23.4	0.038	20.4	24	0.037503	23.6281
18:21	4	15	2	37	23.4	0.045	32	25.6	0.049504	23.3494
18:21	5	15	2	37	23.4	0.036	22.3	25.8	0.043867	25.2197
18:21	6	15	2	37	23.4	0.035	22.1	26.6	0.039823	26.0046
18:21	7	3	2	37	24.16	0.038	19	22	0.048289	21.8598
18:21	8	3	2	37	24.16	0.047	6.1	23.2	0.052008	22.7959
18:21	9	3	2	37	24.16	0.044	10.1	24.4	0.048986	23.9371
18:21	10	3	2	37	24.16	0.036	19.2	25.5	0.045926	24.6891
18:21	11	3	2	37	24.16	0.036	38.2	25.8	0.04024	25.1288
18:21	12	3	2	37	24.16	0.01	17.3	27.8	0.02059	27.093
18:28	1	14	9	38	23.47	0.04	42.5	22.4	0.050552	22.1522
18:28	2	14	9	38	23.47	0.041	22	22.9	0.046117	22.495
18:28	3	14	9	38	23.47	0.038	24.2	24	0.037503	23.6281
18:28	4	14	9	38	23.47	0.05	36.2	25.6	0.05436	23.3494
18:28	5	14	9	38	23.47	0.038	13.8	25.9	0.045838	25.3166
18:28	6	14	9	38	23.47	0.043	20.5	26.9	0.048125	26.2918
18:28	7	4	9	38	24.4	0.047	25.7	22.2	0.056836	22.05
18:28	8	4	9	38	24.4	0.042	20.6	22.8	0.046762	22.4091
18:28	9	4	9	38	24.4	0.041	19	24.5	0.046267	24.0333
18:28	10	4	9	38	24.4	0.04	12.3	25.6	0.049884	24.7851
18:28	11	4	9	38	24.4	0.043	45.2	25.6	0.047345	24.9364
18:28	12	4	9	38	24.4	0.016	6.3	28	0.025984	27.288
18:28	1	14	2	38	23.47	0.04	42.5	22.4	0.050552	22.1522
18:28	2	14	2	38	23.47	0.041	22	22.9	0.046117	22.495
18:28	3	14	2	38	23.47	0.038	24.2	24	0.037503	23.6281
18:28	4	14	2	38	23.47	0.05	36.2	25.6	0.05436	23.3494
18:28	5	14	2	38	23.47	0.038	13.8	25.9	0.045838	25.3166
18:28	6	14	2	38	23.47	0.043	20.5	26.9	0.048125	26.2918
18:28	7	4	2	38	24.4	0.047	25.7	22.2	0.056836	22.05
18:28	8	4	2	38	24.4	0.042	20.6	22.8	0.046762	22.4091
18:28	9	4	2	38	24.4	0.041	19	24.5	0.046267	24.0333
18:28	10	4	2	38	24.4	0.04	12.3	25.6	0.049884	24.7851
18:28	11	4	2	38	24.4	0.043	45.2	25.6	0.047345	24.9364
18:28	12	4	2	38	24.4	0.016	6.3	28	0.025984	27.288
18:35	1	13	9	39	23.54	0.042	36.6	22	0.05252	21.7548
18:35	2	13	9	39	23.54	0.041	9.7	23.2	0.046117	22.7852
18:35	3	13	9	39	23.54	0.035	32.6	24.1	0.034345	23.7231
18:35	4	13	9	39	23.54	0.063	29.9	24.8	0.066986	23.4456
18:35	5	13	9	39	23.54	0.036	20.8	25.7	0.043867	25.1229
18:35	6	13	9	39	23.54	0.043	20.7	26.6	0.048125	26.0046
18:35	7	5	9	39	24.34	0.031	44.6	22.3	0.041641	22.1452
18:35	8	5	9	39	24.34	0.046	20.3	23.3	0.050959	22.8926
18:35	9	5	9	39	24.34	0.039	17.1	24.5	0.044454	24.0333
18:35	10	5	9	39	24.34	0.035	23.1	25.6	0.044936	24.7851

18:35	11	5	9	39	24.34	0.04	24.8	25.8	0.0443	25.1288
18:35	12	5	9	39	24.34	0.016	0	28.2	0.025984	27.483
18:35	1	13	2	39	23.54	0.042	36.6	22	0.05252	21.7548
18:35	2	13	2	39	23.54	0.041	9.7	23.2	0.046117	22.7852
18:35	3	13	2	39	23.54	0.035	32.6	24.1	0.034345	23.7231
18:35	4	13	2	39	23.54	0.063	29.9	24.8	0.066986	23.4456
18:35	5	13	2	39	23.54	0.036	20.8	25.7	0.043867	25.1229
18:35	6	13	2	39	23.54	0.043	20.7	26.6	0.048125	26.0046
18:35	7	5	2	39	24.34	0.031	44.6	22.3	0.041641	22.1452
18:35	8	5	2	39	24.34	0.046	20.3	23.3	0.050959	22.8926
18:35	9	5	2	39	24.34	0.039	17.1	24.5	0.044454	24.0333
18:35	10	5	2	39	24.34	0.035	23.1	25.6	0.044936	24.7851
18:35	11	5	2	39	24.34	0.04	24.8	25.8	0.0443	25.1288
18:35	12	5	2	39	24.34	0.016	0	28.2	0.025984	27.483
18:42	1	12	9	40	23.68	0.043	22.1	22	0.053503	21.7548
18:42	2	12	9	40	23.68	0.04	19	23.1	0.04516	22.6885
18:42	3	12	9	40	23.68	0.04	29.3	24.2	0.039608	23.818
18:42	4	12	9	40	23.68	0.047	39.4	25.3	0.051446	23.5419
18:42	5	12	9	40	23.68	0.036	25	25.7	0.043867	25.1229
18:42	6	12	9	40	23.68	0.045	23.5	26.5	0.050201	25.9089
18:42	7	6	9	40	24.31	0.042	33.9	22	0.052087	21.8598
18:42	8	6	9	40	24.31	0.047	23.3	23.1	0.052008	22.6992
18:42	9	6	9	40	24.31	0.047	30.1	24.8	0.051706	24.3216
18:42	10	6	9	40	24.31	0.035	11.5	25.6	0.044936	24.7851
18:42	11	6	9	40	24.31	0.039	19.8	25.8	0.043285	25.1288
18:42	12	6	9	40	24.31	0.016	0	28.4	0.025984	27.678
18:42	1	12	2	40	23.68	0.043	22.1	22	0.053503	21.7548
18:42	2	12	2	40	23.68	0.04	19	23.1	0.04516	22.6885
18:42	3	12	2	40	23.68	0.04	29.3	24.2	0.039608	23.818
18:42	4	12	2	40	23.68	0.047	39.4	25.3	0.051446	23.5419
18:42	5	12	2	40	23.68	0.036	25	25.7	0.043867	25.1229
18:42	6	12	2	40	23.68	0.045	23.5	26.5	0.050201	25.9089
18:42	7	6	2	40	24.31	0.042	33.9	22	0.052087	21.8598
18:42	8	6	2	40	24.31	0.047	23.3	23.1	0.052008	22.6992
18:42	9	6	2	40	24.31	0.047	30.1	24.8	0.051706	24.3216
18:42	10	6	2	40	24.31	0.035	11.5	25.6	0.044936	24.7851
18:42	11	6	2	40	24.31	0.039	19.8	25.8	0.043285	25.1288
18:42	12	6	2	40	24.31	0.016	0	28.4	0.025984	27.678
18:49	1	11	9	41	23.85	0.031	39.7	22.1	0.041698	21.8542
18:49	2	11	9	41	23.85	0.042	35.1	23	0.047073	22.5918
18:49	3	11	9	41	23.85	0.08	18.7	23.6	0.081716	23.2482
18:49	4	11	9	41	23.85	0.075	44.7	24.8	0.07864	22.9644
18:49	5	11	9	41	23.85	0.042	25.9	25.9	0.049778	25.3166
18:49	6	11	9	41	23.85	0.053	24.9	26	0.058503	25.4302
18:49	7	7	9	41	24.37	0.037	35.9	21.9	0.047339	21.7646
18:49	8	7	9	41	24.37	0.049	26	23.2	0.054106	22.7959
18:49	9	7	9	41	24.37	0.088	22.2	23.3	0.088872	22.88
18:49	10	7	9	41	24.37	0.035	14.1	25.6	0.044936	24.7851
18:49	11	7	9	41	24.37	0.039	23.1	25.8	0.043285	25.1288
18:49	12	7	9	41	24.37	0.016	6.2	28.4	0.025984	27.678
18:49	1	11	2	41	23.85	0.031	39.7	22.1	0.041698	21.8542
18:49	2	11	2	41	23.85	0.042	35.1	23	0.047073	22.5918
18:49	3	11	2	41	23.85	0.08	18.7	23.6	0.081716	23.2482
18:49	4	11	2	41	23.85	0.075	44.7	24.8	0.07864	22.9644
18:49	5	11	2	41	23.85	0.042	25.9	25.9	0.049778	25.3166
18:49	6	11	2	41	23.85	0.053	24.9	26	0.058503	25.4302
18:49	7	7	2	41	24.37	0.037	35.9	21.9	0.047339	21.7646
18:49	8	7	2	41	24.37	0.049	26	23.2	0.054106	22.7959

18:49	9	7	2	41	24.37	0.088	22.2	23.3	0.088872	22.88
18:49	10	7	2	41	24.37	0.035	14.1	25.6	0.044936	24.7851
18:49	11	7	2	41	24.37	0.039	23.1	25.8	0.043285	25.1288
18:49	12	7	2	41	24.37	0.016	6.2	28.4	0.025984	27.678
18:55	1	10	9	42	24.1	0.077	23.3	21.2	0.086953	20.9601
18:55	2	10	9	42	24.1	0.055	18.5	23	0.059508	22.5918
18:55	3	10	9	42	24.1	0.08	21.3	24	0.081716	23.6281
18:55	4	10	9	42	24.1	0.04	16	25.9	0.044648	23.3494
18:55	5	10	9	42	24.1	0.042	26.9	26	0.049778	25.4134
18:55	6	10	9	42	24.1	0.051	48.3	26.2	0.056428	25.6216
18:55	7	8	9	42	24.43	0.034	19.3	22.3	0.04449	22.1452
18:55	8	8	9	42	24.43	0.09	9.9	22.6	0.097119	22.2156
18:55	9	8	9	42	24.43	0.056	25.4	24.2	0.059864	23.7449
18:55	10	8	9	42	24.43	0.044	35.2	25.1	0.053842	24.3051
18:55	11	8	9	42	24.43	0.045	21	25.7	0.049375	25.0326
18:55	12	8	9	42	24.43	0.016	6.2	28.2	0.025984	27.483
18:55	1	10	2	42	24.1	0.077	23.3	21.2	0.086953	20.9601
18:55	2	10	2	42	24.1	0.055	18.5	23	0.059508	22.5918
18:55	3	10	2	42	24.1	0.08	21.3	24	0.081716	23.6281
18:55	4	10	2	42	24.1	0.04	16	25.9	0.044648	23.3494
18:55	5	10	2	42	24.1	0.042	26.9	26	0.049778	25.4134
18:55	6	10	2	42	24.1	0.051	48.3	26.2	0.056428	25.6216
18:55	7	8	2	42	24.43	0.034	19.3	22.3	0.04449	22.1452
18:55	8	8	2	42	24.43	0.09	9.9	22.6	0.097119	22.2156
18:55	9	8	2	42	24.43	0.056	25.4	24.2	0.059864	23.7449
18:55	10	8	2	42	24.43	0.044	35.2	25.1	0.053842	24.3051
18:55	11	8	2	42	24.43	0.045	21	25.7	0.049375	25.0326
18:55	12	8	2	42	24.43	0.016	6.2	28.2	0.025984	27.483
19:02	1	9	9	43	24.15	0.037	30.9	21.8	0.047601	21.5561
19:02	2	9	9	43	24.15	0.083	17.5	22.7	0.08629	22.3015
19:02	3	9	9	43	24.15	0.067	29.9	24.4	0.068031	24.008
19:02	4	9	9	43	24.15	0.041	30.8	25.8	0.045619	23.7344
19:02	5	9	9	43	24.15	0.062	30.4	25.5	0.069482	24.9293
19:02	6	9	9	43	24.15	0.09	24.3	25.8	0.096902	25.2387
19:02	1	9	2	43	24.15	0.037	30.9	21.8	0.047339	21.6695
19:02	2	9	2	43	24.15	0.083	17.5	22.7	0.089775	22.3123
19:02	3	9	2	43	24.15	0.067	29.9	24.4	0.069836	23.9371
19:02	4	9	2	43	24.15	0.041	30.8	25.8	0.050874	24.9771
19:02	5	9	2	43	24.15	0.062	30.4	25.5	0.06663	24.8402
19:02	6	9	2	43	24.15	0.09	24.3	25.8	0.09251	25.1431

APPENDIX II

MODIFIED TEST FACILITY DATA

Summary sheet for Room Thermal Comfort Data

Experiment 1 - 17 W/m^2 with 2.7 air changes per hour

Height	Av.Vel	Max.Vel	Min.Vel	Av.Temp	Max.Temp	Min.Temp	Av.PPD	Max.PPD	Min.PPD	Av.PMV	Max.PMV	Min.PMV
0.1	0.043	0.055813	0.028739	23.4	24.3	22.3	5.37	6.62	5	0.1	0.279	-0.099
0.6	0.045	0.047173	0.040031	25.2	25.3	25.1	8.1	9.65	7.4	0.38	0.472	0.34
1.1	0.032	0.048506	0.027228	26.2	26.4	26	13.38	16.66	12.05	0.63	0.744	0.58
1.7	0.043	0.046042	0.036366	26.6	26.9	26.4	15.29	18.73	13.68	0.7	0.807	0.643
2.1	0.048	0.057942	0.037626	26.7	26.9	26.5	15.75	17.49	14.58	0.71	0.77	0.675
2.6	0.048	0.092898	0.027077	26.7	27.1	26.3	15.68	17.13	13.87	0.71	0.759	0.65
0.1	0.044	0.091133	0.027507	23.4	24.4	22.1	5.96	7.77	5	0.18	0.365	-0.047
0.6	0.036	0.04091	0.033769	24.9	25	24.7	7.56	9.63	6.39	0.35	0.471	0.259
1.1	0.041	0.055427	0.03621	26.2	26.4	25.8	12.08	16.66	10.27	0.58	0.744	0.502
1.7	0.038	0.043925	0.03251	26.6	26.8	26.4	13.61	19.11	11.4	0.64	0.818	0.553
2.1	0.049	0.081824	0.036243	26.6	26.8	26.2	13.59	17.69	11.4	0.64	0.776	0.553
2.6	0.058	0.10196	0.037084	26.6	27.1	26.1	13.56	16.37	10.59	0.64	0.735	0.517
Occ.Zone	0.040167	0.091133	0.027228	24.88333	26.4	22.1	8.741667	26.4	5	0.37	26.4	-0.099
(Average of readings below 1.7m)												
ADPI =	42.05608											
Clo value:	0.6											
Ext.Work:	0											
Humidity:	50											
Met.Rate:	1.2											

Detailed Thermal Comfort Data

Experiment 1 - 17 W/m^2 with 2.7 air changes per hour

			Test Start Date:7\8\1996														
			Measurement Time: 180 secs.														
X-Pos (m)	Y-Pos (m)	Height (m)	Time	Rel.Time	Vel	Turb'ce	Temp	Read'g	Globe temp	Corr'd Vel	Corr'd Temp	Shift Temp	Shift Globe Temp	Rad.Temp	DR	PPD	PMV
0.75	0.25	0.1	18:0	00:50:12	0.026	40.5	23.4	9		0.029	22.9	22.9		25.3	0	5	-0.003
1.75	0.25	0.1	18:0	00:57:20	0.046	26.3	24	10		0.048	23.5	23.5		25.3	0	5.19	0.097
2.25	0.25	0.1	19:0	02:16:01	0.044	28.4	24.8	22		0.046	24.3	24.3		25.7	0	6.62	0.279
2.75	0.25	0.1	18:0	00:57:20	0.046	26.3	24	32		0.048	23.5	23.5		25.3	0	5.19	0.097
3.75	0.25	0.1	18:0	00:50:12	0.026	40.5	23.4	31		0.029	22.9	22.9		25.3	0	5	-0.003
0.75	0.75	0.1	18:0	00:42:15	0.054	10.4	22.9	8		0.056	22.4	22.4		25.33	1.6	5.14	-0.083
1.75	0.75	0.1	18:0	01:03:28	0.052	24.4	23.9	11		0.054	23.4	23.4		25.27	1.2	5.12	0.076
2.75	0.75	0.1	18:0	01:03:28	0.052	24.4	23.9	33		0.054	23.4	23.4		25.27	1.2	5.12	0.076
3.75	0.75	0.1	18:0	00:42:15	0.054	10.4	22.9	30		0.056	22.4	22.4		25.33	1.6	5.14	-0.083
0.75	1.25	0.1	18:0	00:36:47	0.03	15.1	23.8	7		0.033	23.3	23.3		25.32	0	5.09	0.066
1.75	1.25	0.1	18:0	01:09:40	0.046	22.3	23.9	12		0.048	23.4	23.4		25.23	0	5.1	0.071
2.25	1.25	0.1	19:0	02:09:56	0.044	23.1	24.7	21		0.046	24.2	24.2		25.6	0	6.3	0.25
2.75	1.25	0.1	18:0	01:09:40	0.046	22.3	23.9	34		0.048	23.4	23.4		25.23	0	5.1	0.071
3.75	1.25	0.1	18:0	00:36:47	0.03	15.1	23.8	29		0.033	23.3	23.3		25.32	0	5.09	0.066
0.75	1.75	0.1	18:0	00:29:58	0.026	39	22.8	6		0.029	22.3	22.3		25.33	0	5.2	-0.099
1.75	1.75	0.1	18:0	01:16:12	0.037	30.3	24.2	13		0.039	23.7	23.7		25.17	0	5.26	0.113
2.75	1.75	0.1	18:0	01:16:12	0.037	30.3	24.2	35		0.039	23.7	23.7		25.17	0	5.26	0.113
3.75	1.75	0.1	18:0	00:29:58	0.026	39	22.8	28		0.029	22.3	22.3		25.33	0	5.2	-0.099
0.75	2.25	0.1	18:0	00:23:53	0.038	22.9	23.8	5		0.04	23.3	23.3		25.42	0	5.13	0.079
1.75	2.25	0.1	19:0	01:22:32	0.042	19	24.5	14		0.044	24	24		25.32	0	5.69	0.182
2.25	2.25	0.1	19:0	02:02:53	0.042	18.9	24.6	20		0.044	24.1	24.1		25.53	0	6.05	0.225
2.75	2.25	0.1	19:0	01:22:32	0.042	19	24.5	36		0.044	24	24		25.32	0	5.69	0.182
3.75	2.25	0.1	18:0	00:23:53	0.038	22.9	23.8	27		0.04	23.3	23.3		25.42	0	5.13	0.079
0.75	2.75	0.1	18:0	00:18:05	0.036	39.2	23.8	4		0.038	23.3	23.3		25.32	0	5.09	0.066
1.75	2.75	0.1	19:0	01:28:23	0.035	26.4	24	15		0.037	23.5	23.5		25.42	0	5.26	0.112
2.75	2.75	0.1	19:0	01:28:23	0.035	26.4	24	37		0.037	23.5	23.5		25.42	0	5.26	0.112
3.75	2.75	0.1	18:0	00:18:05	0.036	39.2	23.8	26		0.038	23.3	23.3		25.32	0	5.09	0.066
0.75	3.25	0.1	17:0	00:12:09	0.044	31.6	23.6	3		0.046	23.1	23.1		25.62	0	5.1	0.071
2.25	3.25	0.1	19:0	01:55:58	0.048	21.4	24.4	19		0.05	23.9	23.9		25.63	0	5.87	0.205
3.75	3.25	0.1	17:0	00:12:09	0.044	31.6	23.6	25		0.046	23.1	23.1		25.62	0	5.1	0.071
0.75	3.75	0.1	17:0	00:06:03	0.05	26.8	23.8	2		0.052	23.3	23.3		25.55	0.8	5.19	0.095
1.75	3.75	0.1	19:0	01:35:25	0.046	25.9	24.4	16		0.048	23.9	23.9		25.58	0	5.81	0.198
2.75	3.75	0.1	19:0	01:35:25	0.046	25.9	24.4	38		0.048	23.9	23.9		25.58	0	5.81	0.198
3.75	3.75	0.1	17:0	00:06:03	0.05	26.8	23.8	24		0.052	23.3	23.3		25.55	0.8	5.19	0.095
0.75	4.25	0.1	17:0	00:00:00	0.028	45.7	23.3	1		0.031	22.8	22.8		25.62	0	5.01	0.021
1.75	4.25	0.1	19:0	01:41:54	0.046	27	24.4	17		0.048	23.9	23.9		25.94	0	6.24	0.244
2.25	4.25	0.1	19:0	01:49:03	0.044	29.2	24	18		0.046	23.5	23.5		25.62	0	5.39	0.137

2.75	4.25	0.1	19:0	01:41:54	0.046	27	24.4	39		0.048	23.9	23.9		25.94	0	6.24	0.244
3.75	4.25	0.1	17:0	00:00:00	0.028	45.7	23.3	23		0.031	22.8	22.8		25.62	0	5.01	0.021
0.75	0.25	0.6	18:0	00:50:12	0.041	3.2	25.6	9	25.22	0.045	25.1	25.1	25.22	25.3	0	7.65	0.357
1.75	0.25	0.6	18:0	00:57:20	0.041	9.8	25.6	10	25.22	0.045	25.1	25.1	25.22	25.3	0	7.65	0.357
2.25	0.25	0.6	19:0	02:16:01	0.036	25.2	25.6	22	25.47	0.04	25.1	25.1	25.47	25.7	0	8.49	0.409
2.75	0.25	0.6	18:0	00:57:20	0.041	9.8	25.6	32	25.22	0.045	25.1	25.1	25.22	25.3	0	7.65	0.357
3.75	0.25	0.6	18:0	00:50:12	0.041	3.2	25.6	31	25.22	0.045	25.1	25.1	25.22	25.3	0	7.65	0.357
0.75	0.75	0.6	18:0	00:42:15	0.04	10.1	25.6	8	25.24	0.044	25.1	25.1	25.24	25.33	0	7.71	0.361
1.75	0.75	0.6	18:0	01:03:28	0.041	7	25.8	11	25.28	0.045	25.3	25.3	25.28	25.27	0	8.09	0.385
2.75	0.75	0.6	18:0	01:03:28	0.041	7	25.8	33	25.28	0.045	25.3	25.3	25.28	25.27	0	8.09	0.385
3.75	0.75	0.6	18:0	00:42:15	0.04	10.1	25.6	30	25.24	0.044	25.1	25.1	25.24	25.33	0	7.71	0.361
0.75	1.25	0.6	18:0	00:36:47	0.041	0	25.6	7	25.23	0.045	25.1	25.1	25.23	25.32	0	7.7	0.36
1.75	1.25	0.6	18:0	01:09:40	0.039	10.2	25.8	12	25.26	0.043	25.3	25.3	25.26	25.23	0	8.01	0.38
2.25	1.25	0.6	19:0	02:09:56	0.041	0	25.7	21	25.44	0.045	25.2	25.2	25.44	25.6	0	8.54	0.412
2.75	1.25	0.6	18:0	01:09:40	0.039	10.2	25.8	34	25.26	0.043	25.3	25.3	25.26	25.23	0	8.01	0.38
3.75	1.25	0.6	18:0	00:36:47	0.041	0	25.6	29	25.23	0.045	25.1	25.1	25.23	25.32	0	7.7	0.36
0.75	1.75	0.6	18:0	00:29:58	0.04	5	25.6	6	25.24	0.044	25.1	25.1	25.24	25.33	0	7.71	0.361
1.75	1.75	0.6	18:0	01:16:12	0.041	4.9	25.6	13	25.14	0.045	25.1	25.1	25.14	25.17	0	7.4	0.34
2.75	1.75	0.6	18:0	01:16:12	0.041	4.9	25.6	35	25.14	0.045	25.1	25.1	25.14	25.17	0	7.4	0.34
3.75	1.75	0.6	18:0	00:29:58	0.04	5	25.6	28	25.24	0.044	25.1	25.1	25.24	25.33	0	7.71	0.361
0.75	2.25	0.6	18:0	00:23:53	0.04	7	25.6	5	25.29	0.044	25.1	25.1	25.29	25.42	0	7.9	0.373
1.75	2.25	0.6	19:0	01:22:32	0.039	8.8	25.6	14	25.23	0.043	25.1	25.1	25.23	25.32	0	7.7	0.36
2.25	2.25	0.6	19:0	02:02:53	0.041	4.9	25.7	20	25.4	0.045	25.2	25.2	25.4	25.53	0	8.38	0.403
2.75	2.25	0.6	19:0	01:22:32	0.039	8.8	25.6	36	25.23	0.043	25.1	25.1	25.23	25.32	0	7.7	0.36
3.75	2.25	0.6	18:0	00:23:53	0.04	7	25.6	27	25.29	0.044	25.1	25.1	25.29	25.42	0	7.9	0.373
0.75	2.75	0.6	18:0	00:18:05	0.041	6.9	25.6	4	25.23	0.045	25.1	25.1	25.23	25.32	0	7.7	0.36
1.75	2.75	0.6	19:0	01:28:23	0.04	5	25.6	15	25.29	0.044	25.1	25.1	25.29	25.42	0	7.9	0.373
2.75	2.75	0.6	19:0	01:28:23	0.04	5	25.6	37	25.29	0.044	25.1	25.1	25.29	25.42	0	7.9	0.373
3.75	2.75	0.6	18:0	00:18:05	0.041	6.9	25.6	26	25.23	0.045	25.1	25.1	25.23	25.32	0	7.7	0.36
0.75	3.25	0.6	17:0	00:12:09	0.041	6.9	25.7	3	25.45	0.045	25.2	25.2	25.45	25.62	0	8.57	0.414
2.25	3.25	0.6	19:0	01:55:58	0.04	8.7	25.6	19	25.42	0.044	25.1	25.1	25.42	25.63	0	8.33	0.4
3.75	3.25	0.6	17:0	00:12:09	0.041	6.9	25.7	25	25.45	0.045	25.2	25.2	25.45	25.62	0	8.57	0.414
0.75	3.75	0.6	17:0	00:06:03	0.041	0	25.7	2	25.41	0.045	25.2	25.2	25.41	25.55	0	8.42	0.405
1.75	3.75	0.6	19:0	01:35:25	0.04	16.6	25.8	16	25.47	0.044	25.3	25.3	25.47	25.58	0	8.77	0.425
2.75	3.75	0.6	19:0	01:35:25	0.04	16.6	25.8	38	25.47	0.044	25.3	25.3	25.47	25.58	0	8.77	0.425
3.75	3.75	0.6	17:0	00:06:03	0.041	0	25.7	24	25.41	0.045	25.2	25.2	25.41	25.55	0	8.42	0.405
0.75	4.25	0.6	17:0	00:00:00	0.041	0	25.6	1	25.41	0.045	25.1	25.1	25.41	25.62	0	8.3	0.398
1.75	4.25	0.6	19:0	01:41:54	0.043	13.2	25.8	17	25.68	0.047	25.3	25.3	25.68	25.94	0	9.65	0.472
2.25	4.25	0.6	19:0	01:49:03	0.04	9.9	25.7	18	25.45	0.044	25.2	25.2	25.45	25.62	0	8.57	0.414
2.75	4.25	0.6	19:0	01:41:54	0.043	13.2	25.8	39	25.68	0.047	25.3	25.3	25.68	25.94	0	9.65	0.472
3.75	4.25	0.6	17:0	00:00:00	0.041	0	25.6	23	25.41	0.045	25.1	25.1	25.41	25.62	0	8.3	0.398
0.75	0.25	1.1	18:0	00:50:12	0.041	8.5	26.5	9	26.01	0.03	26.1	26.1	26.01	25.96	0	12.6	0.602
1.75	0.25	1.1	18:0	00:57:20	0.039	0	26.5	10	26.06	0.028	26.1	26.1	26.06	26.04	0	12.9	0.613
2.25	0.25	1.1	19:0	02:16:01	0.044	4.5	26.7	22	26.42	0.034	26.3	26.3	26.42	26.49	0	15.4	0.703
2.75	0.25	1.1	18:0	00:57:20	0.039	0	26.5	32	26.06	0.028	26.1	26.1	26.06	26.04	0	12.9	0.613
3.75	0.25	1.1	18:0	00:50:12	0.041	8.5	26.5	31	26.01	0.03	26.1	26.1	26.01	25.96	0	12.6	0.602
0.75	0.75	1.1	18:0	00:42:15	0.042	6.7	26.5	8	26.02	0.031	26.1	26.1	26.02	25.98	0	12.7	0.605
1.75	0.75	1.1	18:0	01:03:28	0.038	10.5	26.6	11	26.11	0.027	26.2	26.2	26.11	26.06	0	13.4	0.631
2.75	0.75	1.1	18:0	01:03:28	0.038	10.5	26.6	33	26.11	0.027	26.2	26.2	26.11	26.06	0	13.4	0.631
3.75	0.75	1.1	18:0	00:42:15	0.042	6.7	26.5	30	26.02	0.031	26.1	26.1	26.02	25.98	0	12.7	0.605
0.75	1.25	1.1	18:0	00:36:47	0.042	6.7	26.5	7	25.96	0.031	26.1	26.1	25.96	25.88	0	12.4	0.592
1.75	1.25	1.1	18:0	01:09:40	0.041	9.8	26.8	12	26.1	0.03	26.4	26.4	26.1	25.93	0	13.8	0.646
2.25	1.25	1.1	19:0	02:09:56	0.044	4.5	26.7	21	26.26	0.034	26.3	26.3	26.26	26.24	0	14.5	0.671
2.75	1.25	1.1	18:0	01:09:40	0.041	9.8	26.8	34	26.1	0.03	26.4	26.4	26.1	25.93	0	13.8	0.646
3.75	1.25	1.1	18:0	00:36:47	0.042	6.7	26.5	29	25.96	0.031	26.1	26.1	25.96	25.88	0	12.4	0.592
0.75	1.75	1.1	18:0	00:29:58	0.042	6.7	26.4	6	25.96	0.031	26	26	25.96	25.94	0	12.2	0.584
1.75	1.75	1.1	18:0	01:16:12	0.04	16.7	26.7	13	26.05	0.029	26.3	26.3	26.05	25.91	0	13.3	0.627
2.75	1.75	1.1	18:0	01:16:12	0.04	16.7	26.7	35	26.05	0.029	26.3	26.3	26.05	25.91	0	13.3	0.627
3.75	1.75	1.1	18:0	00:29:58	0.042	6.7	26.4	28	25.96	0.031	26	26	25.96	25.94	0	12.2	0.584
0.75	2.25	1.1	18:0	00:23:53	0.042	10.8	26.4	5	26.05	0.031	26	26	26.05	26.08	0	12.6	0.602
1.75	2.25	1.1	19:0	01:22:32	0.044	8	26.6	14	26.08	0.034	26.2	26.2	26.08	26.01	0	13.2	0.625
2.25	2.25	1.1	19:0	02:02:53	0.042	9.5	26.6	20	26.26	0.031	26.2	26.2	26.26	26.29	0	14.2	0.661
2.75	2.25	1.1	19:0	01:22:32	0.044	8	26.6	36	26.08	0.034	26.2	26.2	26.08	26.01	0	13.2	0.625
3.75	2.25	1.1	18:0	00:23:53	0.042	10.8	26.4	27	26.05	0.031	26	26	26.05	26.08	0	12.6	0.602
0.75	2.75	1.1	18:0	00:18:05	0.042	6.7	26.4	4	25.94	0.031	26	26	25.94	25.91	0	12.1	0.58
1.75	2.75	1.1	19:0	01:28:23	0.038	17.4	26.6	15	26.12	0.027	26.2	26.2	26.12	26.08	0	13.4	0.634
2.75	2.75	1.1	19:0	01:28:23	0.038	17.4	26.6	37	26.12	0.027	26.2	26.2	26.12	26.08	0	13.4	0.634
3.75	2.75	1.1	18:0	00:18:05	0.042	6.7	26.4	26	25.94	0.031	26	26	25.94	25.91	0	12.1	0.58
0.75	3.25	1.1	17:0	00:12:09	0.043	4.7	26.5	3	26.1	0.033	26.1	26.1	26.1	26.1	0	13.1	0.621
2.25	3.25	1.1	19:0	01:55:58	0.042	9.5	26.7	19	26.32	0.031	26.3	26.3	26.32	26.33	0	14.8	0.682

3.75	3.25	1.1	17:0	00:12:09	0.043	4.7	26.5	25	26.1	0.033	26.1	26.1	26.1	26.1	0	13.1	0.621
0.75	3.75	1.1	17:0	00:06:03	0.041	15.5	26.4	2	26.07	0.03	26	26	26.07	26.11	0	12.7	0.606
1.75	3.75	1.1	19:0	01:35:25	0.058	29.8	26.5	16	26.32	0.049	26.1	26.1	26.32	26.47	0	14.4	0.669
2.75	3.75	1.1	19:0	01:35:25	0.058	29.8	26.5	38	26.32	0.049	26.1	26.1	26.32	26.47	0	14.4	0.669
3.75	3.75	1.1	17:0	00:06:03	0.041	15.5	26.4	24	26.07	0.03	26	26	26.07	26.11	0	12.7	0.606
0.75	4.25	1.1	17:0	00:00:00	0.043	4.7	26.4	1	26.14	0.033	26	26	26.14	26.22	0	13.1	0.62
1.75	4.25	1.1	19:0	01:41:54	0.043	16.2	26.8	17	26.58	0.033	26.4	26.4	26.58	26.68	0	16.7	0.744
2.25	4.25	1.1	19:0	01:49:03	0.041	4.9	26.7	18	26.29	0.03	26.3	26.3	26.29	26.28	0	14.6	0.676
2.75	4.25	1.1	19:0	01:41:54	0.043	16.2	26.8	39	26.58	0.033	26.4	26.4	26.58	26.68	0	16.7	0.744
3.75	4.25	1.1	17:0	00:00:00	0.043	4.7	26.4	23	26.14	0.033	26	26	26.14	26.22	0	13.1	0.62
0.75	0.25	1.7	18:0	00:50:12	0.042	4.8	27.2	9		0.043	26.6	26.6		25.96	0	14.8	0.681
1.75	0.25	1.7	18:0	00:57:20	0.042	4.8	27.2	10		0.043	26.6	26.6		26.04	0	15.1	0.692
2.25	0.25	1.7	19:0	02:16:01	0.042	9.5	27.3	22		0.043	26.7	26.7		26.49	0	17.4	0.766
2.75	0.25	1.7	18:0	00:57:20	0.042	4.8	27.2	32		0.043	26.6	26.6		26.04	0	15.1	0.692
3.75	0.25	1.7	18:0	00:50:12	0.042	4.8	27.2	31		0.043	26.6	26.6		25.96	0	14.8	0.681
0.75	0.75	1.7	18:0	00:42:15	0.041	12	27.2	8		0.042	26.6	26.6		25.98	0	14.8	0.684
1.75	0.75	1.7	18:0	01:03:28	0.045	6.3	27.2	11		0.046	26.6	26.6		26.06	0	15.1	0.694
2.75	0.75	1.7	18:0	01:03:28	0.045	6.3	27.2	33		0.046	26.6	26.6		26.06	0	15.1	0.694
3.75	0.75	1.7	18:0	00:42:15	0.041	12	27.2	30		0.042	26.6	26.6		25.98	0	14.8	0.684
0.75	1.25	1.7	18:0	00:36:47	0.042	4.8	27.1	7		0.043	26.5	26.5		25.88	0	14	0.655
1.75	1.25	1.7	18:0	01:09:40	0.042	8.4	27.3	12		0.043	26.7	26.7		25.93	0	15.1	0.693
2.25	1.25	1.7	19:0	02:09:56	0.044	0	27.2	21		0.045	26.6	26.6		26.24	0	15.9	0.718
2.75	1.25	1.7	18:0	01:09:40	0.042	8.4	27.3	34		0.043	26.7	26.7		25.93	0	15.1	0.693
3.75	1.25	1.7	18:0	00:36:47	0.042	4.8	27.1	29		0.043	26.5	26.5		25.88	0	14	0.655
0.75	1.75	1.7	18:0	00:29:58	0.042	8.4	27.2	6		0.043	26.6	26.6		25.94	0	14.7	0.679
1.75	1.75	1.7	18:0	01:16:12	0.044	4.6	27.2	13		0.045	26.6	26.6		25.91	0	14.6	0.675
2.75	1.75	1.7	18:0	01:16:12	0.044	4.6	27.2	35		0.045	26.6	26.6		25.91	0	14.6	0.675
3.75	1.75	1.7	18:0	00:29:58	0.042	8.4	27.2	28		0.043	26.6	26.6		25.94	0	14.7	0.679
0.75	2.25	1.7	18:0	00:23:53	0.042	9.5	27.1	5		0.043	26.5	26.5		26.08	0	14.8	0.681
1.75	2.25	1.7	19:0	01:22:32	0.042	9.6	27.2	14		0.043	26.6	26.6		26.01	0	15	0.688
2.25	2.25	1.7	19:0	02:02:53	0.035	22.4	27.5	20		0.036	26.9	26.9		26.29	0	17.5	0.771
2.75	2.25	1.7	19:0	01:22:32	0.042	9.6	27.2	36		0.043	26.6	26.6		26.01	0	15	0.688
3.75	2.25	1.7	18:0	00:23:53	0.042	9.5	27.1	27		0.043	26.5	26.5		26.08	0	14.8	0.681
0.75	2.75	1.7	18:0	00:18:05	0.043	4.7	27	4		0.044	26.4	26.4		25.91	0	13.7	0.643
1.75	2.75	1.7	19:0	01:28:23	0.04	8.6	27.2	15		0.041	26.6	26.6		26.08	0	15.2	0.697
2.75	2.75	1.7	19:0	01:28:23	0.04	8.6	27.2	37		0.041	26.6	26.6		26.08	0	15.2	0.697
3.75	2.75	1.7	18:0	00:18:05	0.043	4.7	27	26		0.044	26.4	26.4		25.91	0	13.7	0.643
0.75	3.25	1.7	17:0	00:12:09	0.045	9	27	3		0.046	26.4	26.4		26.1	0	14.4	0.668
2.25	3.25	1.7	19:0	01:55:58	0.042	6.8	27.2	19		0.043	26.6	26.6		26.33	0	16.2	0.73
3.75	3.25	1.7	17:0	00:12:09	0.045	9	27	25		0.046	26.4	26.4		26.1	0	14.4	0.668
0.75	3.75	1.7	17:0	00:06:03	0.044	6.5	27	2		0.045	26.4	26.4		26.11	0	14.4	0.669
1.75	3.75	1.7	19:0	01:35:25	0.044	28.7	27.2	16		0.045	26.6	26.6		26.47	0	16.8	0.748
2.75	3.75	1.7	19:0	01:35:25	0.044	28.7	27.2	38		0.045	26.6	26.6		26.47	0	16.8	0.748
3.75	3.75	1.7	17:0	00:06:03	0.044	6.5	27	24		0.045	26.4	26.4		26.11	0	14.4	0.669
0.75	4.25	1.7	17:0	00:00:00	0.041	8.4	27.1	1		0.042	26.5	26.5		26.22	0	15.3	0.7
1.75	4.25	1.7	19:0	01:41:54	0.035	21.4	27.4	17		0.036	26.8	26.8		26.68	0	18.7	0.807
2.25	4.25	1.7	19:0	01:49:03	0.041	6.9	27.3	18		0.042	26.7	26.7		26.28	0	16.5	0.739
2.75	4.25	1.7	19:0	01:41:54	0.035	21.4	27.4	39		0.036	26.8	26.8		26.68	0	18.7	0.807
3.75	4.25	1.7	17:0	00:00:00	0.041	8.4	27.1	23		0.042	26.5	26.5		26.22	0	15.3	0.7
0.75	0.25	2.1	18:0	00:50:12	0.057	42.5	26.9	9		0.058	26.6	26.6		25.96	1.5	14.8	0.681
1.75	0.25	2.1	18:0	00:57:20	0.036	32.4	27	10		0.038	26.7	26.7		26.04	0	15.5	0.707
2.25	0.25	2.1	19:0	02:16:01	0.051	26.6	26.9	22		0.052	26.6	26.6		26.49	0.6	16.9	0.751
2.75	0.25	2.1	18:0	00:57:20	0.036	32.4	27	32		0.038	26.7	26.7		26.04	0	15.5	0.707
3.75	0.25	2.1	18:0	00:50:12	0.057	42.5	26.9	31		0.058	26.6	26.6		25.96	1.5	14.8	0.681
0.75	0.75	2.1	18:0	00:42:15	0.048	13.2	27	8		0.049	26.7	26.7		25.98	0	15.3	0.699
1.75	0.75	2.1	18:0	01:03:28	0.045	16.8	27	11		0.046	26.7	26.7		26.06	0	15.6	0.71
2.75	0.75	2.1	18:0	01:03:28	0.045	16.8	27	33		0.046	26.7	26.7		26.06	0	15.6	0.71
3.75	0.75	2.1	18:0	00:42:15	0.048	13.2	27	30		0.049	26.7	26.7		25.98	0	15.3	0.699
0.75	1.25	2.1	18:0	00:36:47	0.04	17.3	27.2	7		0.041	26.9	26.9		25.88	0	15.9	0.718
1.75	1.25	2.1	18:0	01:09:40	0.049	15.2	27	12		0.05	26.7	26.7		25.93	0.1	15.1	0.693
2.25	1.25	2.1	19:0	02:09:56	0.043	18.8	27.2	21		0.044	26.9	26.9		26.24	0	17.3	0.765
2.75	1.25	2.1	18:0	01:09:40	0.049	15.2	27	34		0.05	26.7	26.7		25.93	0.1	15.1	0.693
3.75	1.25	2.1	18:0	00:36:47	0.04	17.3	27.2	29		0.041	26.9	26.9		25.88	0	15.9	0.718
0.75	1.75	2.1	18:0	00:29:58	0.042	26.7	27	6		0.043	26.7	26.7		25.94	0	15.1	0.694
1.75	1.75	2.1	18:0	01:16:12	0.049	20.8	27	13		0.05	26.7	26.7		25.91	0.1	15	0.69
2.75	1.75	2.1	18:0	01:16:12	0.049	20.8	27	35		0.05	26.7	26.7		25.91	0.1	15	0.69
3.75	1.75	2.1	18:0	00:29:58	0.042	26.7	27	28		0.043	26.7	26.7		25.94	0	15.1	0.694
0.75	2.25	2.1	18:0	00:23:53	0.044	11.2	27	5		0.045	26.7	26.7		26.08	0	15.7	0.713
1.75	2.25	2.1	19:0	01:22:32	0.056	34.9	26.9	14		0.057	26.6	26.6		26.01	1.3	15	0.688
2.25	2.25	2.1	19:0	02:02:53	0.045	8.9	27	20		0.046	26.7	26.7		26.29	0	16.5	0.74

2.75	2.25	2.1	19:0	01:22:32	0.056	34.9	26.9	36		0.057	26.6	26.6		26.01	1.3	15	0.688
3.75	2.25	2.1	18:0	00:23:53	0.044	11.2	27	27		0.045	26.7	26.7		26.08	0	15.7	0.713
0.75	2.75	2.1	18:0	00:18:05	0.045	7.7	26.9	4		0.046	26.6	26.6		25.91	0	14.6	0.675
1.75	2.75	2.1	19:0	01:28:23	0.045	8.9	27	15		0.046	26.7	26.7		26.08	0	15.7	0.713
2.75	2.75	2.1	19:0	01:28:23	0.045	8.9	27	37		0.046	26.7	26.7		26.08	0	15.7	0.713
3.75	2.75	2.1	18:0	00:18:05	0.045	7.7	26.9	26		0.046	26.6	26.6		25.91	0	14.6	0.675
0.75	3.25	2.1	17:0	00:12:09	0.041	15.5	27	3		0.042	26.7	26.7		26.1	0	15.8	0.715
2.25	3.25	2.1	19:0	01:55:58	0.051	25.4	26.9	19		0.052	26.6	26.6		26.33	0.6	16.2	0.73
3.75	3.25	2.1	17:0	00:12:09	0.041	15.5	27	25		0.042	26.7	26.7		26.1	0	15.8	0.715
0.75	3.75	2.1	17:0	00:06:03	0.045	6.3	26.9	2		0.046	26.6	26.6		26.11	0	15.3	0.701
1.75	3.75	2.1	19:0	01:35:25	0.055	24.3	27	16		0.056	26.7	26.7		26.47	1.1	17.3	0.764
2.75	3.75	2.1	19:0	01:35:25	0.055	24.3	27	38		0.056	26.7	26.7		26.47	1.1	17.3	0.764
3.75	3.75	2.1	17:0	00:06:03	0.045	6.3	26.9	24		0.046	26.6	26.6		26.11	0	15.3	0.701
0.75	4.25	2.1	17:0	00:00:00	0.047	13.5	27	1		0.048	26.7	26.7		26.22	0	16.3	0.731
1.75	4.25	2.1	19:0	01:41:54	0.056	24.6	26.8	17		0.057	26.5	26.5		26.68	1.3	17.2	0.76
2.25	4.25	2.1	19:0	01:49:03	0.043	18.8	27.2	18		0.044	26.9	26.9		26.28	0	17.5	0.77
2.75	4.25	2.1	19:0	01:41:54	0.056	24.6	26.8	39		0.057	26.5	26.5		26.68	1.3	17.2	0.76
3.75	4.25	2.1	17:0	00:00:00	0.047	13.5	27	23		0.048	26.7	26.7		26.22	0	16.3	0.731
0.75	0.25	2.6	18:0	00:50:12	0.057	27.5	26.9	9		0.049	26.4	26.4		25.96	0	13.9	0.65
1.75	0.25	2.6	18:0	00:57:20	0.059	27.7	26.9	10		0.052	26.4	26.4		26.04	0.5	14.2	0.66
2.25	0.25	2.6	19:0	02:16:01	0.075	29.9	26.9	22		0.069	26.4	26.4		26.49	2.6	15.9	0.719
2.75	0.25	2.6	18:0	00:57:20	0.059	27.7	26.9	32		0.052	26.4	26.4		26.04	0.5	14.2	0.66
3.75	0.25	2.6	18:0	00:50:12	0.057	27.5	26.9	31		0.049	26.4	26.4		25.96	0	13.9	0.65
0.75	0.75	2.6	18:0	00:42:15	0.039	28.4	27.3	8		0.029	26.8	26.8		25.98	0	15.8	0.715
1.75	0.75	2.6	18:0	01:03:28	0.054	36.5	27	11		0.046	26.5	26.5		26.06	0	14.7	0.679
2.75	0.75	2.6	18:0	01:03:28	0.054	36.5	27	33		0.046	26.5	26.5		26.06	0	14.7	0.679
3.75	0.75	2.6	18:0	00:42:15	0.039	28.4	27.3	30		0.029	26.8	26.8		25.98	0	15.8	0.715
0.75	1.25	2.6	18:0	00:36:47	0.044	18.9	27.6	7		0.035	27.1	27.1		25.88	0	16.8	0.749
1.75	1.25	2.6	18:0	01:09:40	0.057	27.7	27.4	12		0.049	26.9	26.9		25.93	0	16	0.724
2.25	1.25	2.6	19:0	02:09:56	0.06	31.9	27.3	21		0.053	26.8	26.8		26.24	0.7	16.8	0.749
2.75	1.25	2.6	18:0	01:09:40	0.057	27.7	27.4	34		0.049	26.9	26.9		25.93	0	16	0.724
3.75	1.25	2.6	18:0	00:36:47	0.044	18.9	27.6	29		0.035	27.1	27.1		25.88	0	16.8	0.749
0.75	1.75	2.6	18:0	00:29:58	0.04	25.4	27.6	6		0.03	27.1	27.1		25.94	0	17	0.756
1.75	1.75	2.6	18:0	01:16:12	0.037	24.5	27.6	13		0.027	27.1	27.1		25.91	0	16.9	0.752
2.75	1.75	2.6	18:0	01:16:12	0.037	24.5	27.6	35		0.027	27.1	27.1		25.91	0	16.9	0.752
3.75	1.75	2.6	18:0	00:29:58	0.04	25.4	27.6	28		0.03	27.1	27.1		25.94	0	17	0.756
0.75	2.25	2.6	18:0	00:23:53	0.043	27.7	27.5	5		0.034	27	27		26.08	0	17.1	0.759
1.75	2.25	2.6	19:0	01:22:32	0.046	29.2	27.4	14		0.037	26.9	26.9		26.01	0	16.4	0.735
2.25	2.25	2.6	19:0	02:02:53	0.044	29.1	27.3	20		0.035	26.8	26.8		26.29	0	17	0.756
2.75	2.25	2.6	19:0	01:22:32	0.046	29.2	27.4	36		0.037	26.9	26.9		26.01	0	16.4	0.735
3.75	2.25	2.6	18:0	00:23:53	0.043	27.7	27.5	27		0.034	27	27		26.08	0	17.1	0.759
0.75	2.75	2.6	18:0	00:18:05	0.052	27.6	27.5	4		0.044	27	27		25.91	0	16.4	0.737
1.75	2.75	2.6	19:0	01:28:23	0.05	33.2	27.1	15		0.042	26.6	26.6		26.08	0	15.2	0.697
2.75	2.75	2.6	19:0	01:28:23	0.05	33.2	27.1	37		0.042	26.6	26.6		26.08	0	15.2	0.697
3.75	2.75	2.6	18:0	00:18:05	0.052	27.6	27.5	26		0.044	27	27		25.91	0	16.4	0.737
0.75	3.25	2.6	17:0	00:12:09	0.058	30.5	27.2	3		0.051	26.7	26.7		26.1	0.2	15.8	0.715
2.25	3.25	2.6	19:0	01:55:58	0.052	31.4	27.1	19		0.044	26.6	26.6		26.33	0	16.2	0.73
3.75	3.25	2.6	17:0	00:12:09	0.058	30.5	27.2	25		0.051	26.7	26.7		26.1	0.2	15.8	0.715
0.75	3.75	2.6	17:0	00:06:03	0.056	33	26.9	2		0.048	26.4	26.4		26.11	0	14.4	0.669
1.75	3.75	2.6	19:0	01:35:25	0.096	27	26.9	16		0.093	26.4	26.4		26.47	4.4	14.7	0.678
2.75	3.75	2.6	19:0	01:35:25	0.096	27	26.9	38		0.093	26.4	26.4		26.47	4.4	14.7	0.678
3.75	3.75	2.6	17:0	00:06:03	0.056	33	26.9	24		0.048	26.4	26.4		26.11	0	14.4	0.669
0.75	4.25	2.6	17:0	00:00:00	0.062	31.6	26.8	1		0.055	26.3	26.3		26.22	1.1	14.4	0.668
1.75	4.25	2.6	19:0	01:41:54	0.09	24.4	26.8	17		0.086	26.3	26.3		26.68	3.9	15.6	0.71
2.25	4.25	2.6	19:0	01:49:03	0.062	30.9	26.9	18		0.055	26.4	26.4		26.28	1.1	15.1	0.692
2.75	4.25	2.6	19:0	01:41:54	0.09	24.4	26.8	39		0.086	26.3	26.3		26.68	3.9	15.6	0.71
3.75	4.25	2.6	17:0	00:00:00	0.062	31.6	26.8	23		0.055	26.3	26.3		26.22	1.1	14.4	0.668
0.25	0.25	0.1	18:0	00:50:12	0.04	13.3	24.4	31		0.037	23.9	23.9		25.96	0	6.27	0.247
1.25	0.25	0.1	18:0	00:57:20	0.048	18.6	24.8	32		0.046	24.3	24.3		26.04	0	7.17	0.323
3.25	0.25	0.1	18:0	00:57:20	0.048	18.6	24.8	10		0.046	24.3	24.3		26.04	0	7.17	0.323
4.25	0.25	0.1	18:0	00:50:12	0.04	13.3	24.4	9		0.037	23.9	23.9		25.96	0	6.27	0.247
0.25	0.75	0.1	18:0	00:42:15	0.046	17.4	24.1	30		0.044	23.6	23.6		25.98	0	5.83	0.2
1.25	0.75	0.1	18:0	01:03:28	0.048	19.6	24.8	33		0.046	24.3	24.3		26.06	0	7.21	0.326
2.25	0.75	0.1	19:0	02:09:56	0.031	46	24.9	21		0.028	24.4	24.4		26.24	0	7.77	0.365
3.25	0.75	0.1	18:0	01:03:28	0.048	19.6	24.8	11		0.046	24.3	24.3		26.06	0	7.21	0.326
4.25	0.75	0.1	18:0	00:42:15	0.046	17.4	24.1	8		0.044	23.6	23.6		25.98	0	5.83	0.2
0.25	1.25	0.1	18:0	00:36:47	0.038	7.4	24.3	29		0.035	23.8	23.8		25.88	0	6	0.22
4.25	1.25	0.1	18:0	00:36:47	0.038	7.4	24.3	7		0.035	23.8	23.8		25.88	0	6	0.22
0.25	1.75	0.1	18:0	00:29:58	0.037	5.4	24.1	28		0.034	23.6	23.6		25.94	0	5.79	0.195
1.25	1.75	0.1	18:0	01:09:40	0.034	25.9	23.9	34		0.031	23.4	23.4		25.93	0	5.53	0.16

2.25	1.75	0.1	19:0	02:02:53	0.046	25.2	24.4	20		0.044	23.9	23.9		26.29	0	6.74	0.289
3.25	1.75	0.1	18:0	01:09:40	0.034	25.9	23.9	12		0.031	23.4	23.4		25.93	0	5.53	0.16
4.25	1.75	0.1	18:0	00:29:58	0.037	5.4	24.1	6		0.034	23.6	23.6		25.94	0	5.79	0.195
0.25	2.25	0.1	18:0	00:23:53	0.089	25.5	22.7	27		0.091	22.2	22.2		26.08	6.5	5.01	-0.022
1.25	2.25	0.1	18:0	01:16:12	0.05	20.4	23	35		0.048	22.5	22.5		25.91	0	5	0.007
3.25	2.25	0.1	18:0	01:16:12	0.05	20.4	23	13		0.048	22.5	22.5		25.91	0	5	0.007
4.25	2.25	0.1	18:0	00:23:53	0.089	25.5	22.7	5		0.091	22.2	22.2		26.08	6.5	5.01	-0.022
0.25	2.75	0.1	18:0	00:18:05	0.037	13.2	24	26		0.034	23.5	23.5		25.91	0	5.63	0.174
1.25	2.75	0.1	19:0	01:22:32	0.065	10.6	22.6	36		0.065	22.1	22.1		26.01	3	5.05	-0.047
2.25	2.75	0.1	19:0	01:55:58	0.048	19.6	24.2	19		0.046	23.7	23.7		26.33	0	6.41	0.261
3.25	2.75	0.1	19:0	01:22:32	0.065	10.6	22.6	14		0.065	22.1	22.1		26.01	3	5.05	-0.047
4.25	2.75	0.1	18:0	00:18:05	0.037	13.2	24	4		0.034	23.5	23.5		25.91	0	5.63	0.174
0.25	3.25	0.1	17:0	00:12:09	0.037	5.5	23.9	25		0.034	23.4	23.4		26.1	0	5.69	0.182
1.25	3.25	0.1	19:0	01:28:23	0.057	17.9	23.1	37		0.056	22.6	22.6		26.08	1.7	5.04	0.046
3.25	3.25	0.1	19:0	01:28:23	0.057	17.9	23.1	15		0.056	22.6	22.6		26.08	1.7	5.04	0.046
4.25	3.25	0.1	17:0	00:12:09	0.037	5.5	23.9	3		0.034	23.4	23.4		26.1	0	5.69	0.182
0.25	3.75	0.1	17:0	00:06:03	0.036	9.7	23.9	24		0.033	23.4	23.4		26.11	0	5.69	0.183
1.25	3.75	0.1	19:0	01:35:25	0.037	22.4	24.3	38		0.034	23.8	23.8		26.47	0	6.82	0.296
2.25	3.75	0.1	19:0	01:49:03	0.047	21.6	24.3	18		0.045	23.8	23.8		26.28	0	6.53	0.271
3.25	3.75	0.1	19:0	01:35:25	0.037	22.4	24.3	16		0.034	23.8	23.8		26.47	0	6.82	0.296
4.25	3.75	0.1	17:0	00:06:03	0.036	9.7	23.9	2		0.033	23.4	23.4		26.11	0	5.69	0.183
0.25	4.25	0.1	17:0	00:00:00	0.035	8.1	24.3	23		0.032	23.8	23.8		26.22	0	6.45	0.264
1.25	4.25	0.1	19:0	01:41:54	0.055	14.6	23.2	39		0.054	22.7	22.7		26.68	1.2	5.4	0.139
3.25	4.25	0.1	19:0	01:41:54	0.055	14.6	23.2	17		0.054	22.7	22.7		26.68	1.2	5.4	0.139
4.25	4.25	0.1	17:0	00:00:00	0.035	8.1	24.3	1		0.032	23.8	23.8		26.22	0	6.45	0.264
0.25	0.25	0.6	18:0	00:50:12	0.046	8.7	25.6	31	25.23	0.037	24.9	24.9	25.23	25.43	0	7.43	0.342
1.25	0.25	0.6	18:0	00:57:20	0.047	10.5	25.7	32	25.64	0.038	25	25	25.64	26.03	0	8.95	0.435
3.25	0.25	0.6	18:0	00:57:20	0.047	10.5	25.7	10	25.64	0.038	25	25	25.64	26.03	0	8.95	0.435
4.25	0.25	0.6	18:0	00:50:12	0.046	8.7	25.6	9	25.23	0.037	24.9	24.9	25.23	25.43	0	7.43	0.342
0.25	0.75	0.6	18:0	00:42:15	0.045	8.9	25.6	30	25.19	0.036	24.9	24.9	25.19	25.36	0	7.31	0.333
1.25	0.75	0.6	18:0	01:03:28	0.05	17.7	25.7	33	25.8	0.041	25	25	25.8	26.31	0	9.63	0.471
2.25	0.75	0.6	19:0	02:09:56	0.048	8.4	25.6	21	25.53	0.039	24.9	24.9	25.53	25.92	0	8.42	0.405
3.25	0.75	0.6	18:0	01:03:28	0.05	17.7	25.7	11	25.8	0.041	25	25	25.8	26.31	0	9.63	0.471
4.25	0.75	0.6	18:0	00:42:15	0.045	8.9	25.6	8	25.19	0.036	24.9	24.9	25.19	25.36	0	7.31	0.333
0.25	1.25	0.6	18:0	00:36:47	0.044	7.9	25.6	29	25.15	0.035	24.9	24.9	25.15	25.3	0	7.2	0.325
4.25	1.25	0.6	18:0	00:36:47	0.044	7.9	25.6	7	25.15	0.035	24.9	24.9	25.15	25.3	0	7.2	0.325
0.25	1.75	0.6	18:0	00:29:58	0.044	8	25.6	28	25.08	0.035	24.9	24.9	25.08	25.19	0	7.01	0.311
1.25	1.75	0.6	18:0	01:09:40	0.045	6.3	25.6	34	25.45	0.036	24.9	24.9	25.45	25.78	0	8.1	0.386
2.25	1.75	0.6	19:0	02:02:53	0.046	8.7	25.6	20	25.37	0.037	24.9	24.9	25.37	25.66	0	7.87	0.371
3.25	1.75	0.6	18:0	01:09:40	0.045	6.3	25.6	12	25.45	0.036	24.9	24.9	25.45	25.78	0	8.1	0.386
4.25	1.75	0.6	18:0	00:29:58	0.044	8	25.6	6	25.08	0.035	24.9	24.9	25.08	25.19	0	7.01	0.311
0.25	2.25	0.6	18:0	00:23:53	0.043	11.5	25.6	27	25.09	0.034	24.9	24.9	25.09	25.2	0	7.02	0.312
1.25	2.25	0.6	18:0	01:16:12	0.044	6.4	25.7	35	25.17	0.035	25	25	25.17	25.27	0	7.36	0.337
3.25	2.25	0.6	18:0	01:16:12	0.044	6.4	25.7	13	25.17	0.035	25	25	25.17	25.27	0	7.36	0.337
4.25	2.25	0.6	18:0	00:23:53	0.043	11.5	25.6	5	25.09	0.034	24.9	24.9	25.09	25.2	0	7.02	0.312
0.25	2.75	0.6	18:0	00:18:05	0.045	6.3	25.6	26	24.99	0.036	24.9	24.9	24.99	25.04	0	6.77	0.292
1.25	2.75	0.6	19:0	01:22:32	0.046	6.2	25.6	36	25.27	0.037	24.9	24.9	25.27	25.49	0	7.53	0.349
2.25	2.75	0.6	19:0	01:55:58	0.048	10.2	25.6	19	25.38	0.039	24.9	24.9	25.38	25.68	0	7.91	0.374
3.25	2.75	0.6	19:0	01:22:32	0.046	6.2	25.6	14	25.27	0.037	24.9	24.9	25.27	25.49	0	7.53	0.349
4.25	2.75	0.6	18:0	00:18:05	0.045	6.3	25.6	4	24.99	0.036	24.9	24.9	24.99	25.04	0	6.77	0.292
0.25	3.25	0.6	17:0	00:12:09	0.044	11.9	25.6	25	25.1	0.035	24.9	24.9	25.1	25.22	0	7.06	0.315
1.25	3.25	0.6	19:0	01:28:23	0.046	6.2	25.6	37	25.3	0.037	24.9	24.9	25.3	25.54	0	7.64	0.356
3.25	3.25	0.6	19:0	01:28:23	0.046	6.2	25.6	15	25.3	0.037	24.9	24.9	25.3	25.54	0	7.64	0.356
4.25	3.25	0.6	17:0	00:12:09	0.044	11.9	25.6	3	25.1	0.035	24.9	24.9	25.1	25.22	0	7.06	0.315
0.25	3.75	0.6	17:0	00:06:03	0.045	10.8	25.6	24	24.99	0.036	24.9	24.9	24.99	25.04	0	6.77	0.292
1.25	3.75	0.6	19:0	01:35:25	0.047	8.6	25.6	38	25.26	0.038	24.9	24.9	25.26	25.48	0	7.52	0.348
2.25	3.75	0.6	19:0	01:49:03	0.044	7.8	25.7	18	25.34	0.035	25	25	25.34	25.54	0	7.88	0.372
3.25	3.75	0.6	19:0	01:35:25	0.047	8.6	25.6	16	25.26	0.038	24.9	24.9	25.26	25.48	0	7.52	0.348
4.25	3.75	0.6	17:0	00:06:03	0.045	10.8	25.6	2	24.99	0.036	24.9	24.9	24.99	25.04	0	6.77	0.292
0.25	4.25	0.6	17:0	00:00:00	0.047	0	25.4	23	24.91	0.038	24.7	24.7	24.91	25.04	0	6.39	0.259
1.25	4.25	0.6	19:0	01:41:54	0.045	11	25.7	39	25.37	0.036	25	25	25.37	25.59	0	7.98	0.378
3.25	4.25	0.6	19:0	01:41:54	0.045	11	25.7	17	25.37	0.036	25	25	25.37	25.59	0	7.98	0.378
4.25	4.25	0.6	17:0	00:00:00	0.047	0	25.4	1	24.91	0.038	24.7	24.7	24.91	25.04	0	6.39	0.259
0.25	0.25	1.1	18:0	00:50:12	0.04	5	26.7	31	25.75	0.04	26.3	26.3	25.75	25.4	0	11.6	0.561
1.25	0.25	1.1	18:0	00:57:20	0.055	31.1	26.2	32	26.42	0.055	25.8	25.8	26.42	26.88	1.2	14.6	0.674
3.25	0.25	1.1	18:0	00:57:20	0.055	31.1	26.2	10	26.42	0.055	25.8	25.8	26.42	26.88	1.2	14.6	0.674
4.25	0.25	1.1	18:0	00:50:12	0.04	5	26.7	9	25.75	0.04	26.3	26.3	25.75	25.4	0	11.6	0.561
0.25	0.75	1.1	18:0	00:42:15	0.041	4.9	26.5	30	25.74	0.041	26.1	26.1	25.74	25.51	0	11.2	0.544
1.25	0.75	1.1	18:0	01:03:28	0.04	14.1	26.8	33	26.57	0.04	26.4	26.4	26.57	26.68	0	16.7	0.744
2.25	0.75	1.1	19:0	02:09:56	0.041	0	26.8	21	26.08	0.041	26.4	26.4	26.08	25.87	0	13.5	0.638

3.25	0.75	1.1	18:0	01:03:28	0.04	14.1	26.8	11	26.57	0.04	26.4	26.4	26.57	26.68	0	16.7	0.744
4.25	0.75	1.1	18:0	00:42:15	0.041	4.9	26.5	8	25.74	0.041	26.1	26.1	25.74	25.51	0	11.2	0.544
0.25	1.25	1.1	18:0	00:36:47	0.041	4.9	26.5	29	25.61	0.041	26.1	26.1	25.61	25.3	0	10.6	0.517
4.25	1.25	1.1	18:0	00:36:47	0.041	4.9	26.5	7	25.61	0.041	26.1	26.1	25.61	25.3	0	10.6	0.517
0.25	1.75	1.1	18:0	00:29:58	0.041	0	26.4	28	25.61	0.041	26	26	25.61	25.36	0	10.4	0.509
1.25	1.75	1.1	18:0	01:09:40	0.039	5.2	26.8	34	26.16	0.039	26.4	26.4	26.16	26.01	0	14	0.656
2.25	1.75	1.1	19:0	02:02:53	0.038	7.4	26.7	20	26.03	0.038	26.3	26.3	26.03	25.86	0	13.1	0.621
3.25	1.75	1.1	18:0	01:09:40	0.039	5.2	26.8	12	26.16	0.039	26.4	26.4	26.16	26.01	0	14	0.656
4.25	1.75	1.1	18:0	00:29:58	0.041	0	26.4	6	25.61	0.041	26	26	25.61	25.36	0	10.4	0.509
0.25	2.25	1.1	18:0	00:23:53	0.039	7.2	26.5	27	25.65	0.039	26.1	26.1	25.65	25.37	0	10.8	0.526
1.25	2.25	1.1	18:0	01:16:12	0.039	7.2	26.8	35	25.86	0.039	26.4	26.4	25.86	25.52	0	12.4	0.592
3.25	2.25	1.1	18:0	01:16:12	0.039	7.2	26.8	13	25.86	0.039	26.4	26.4	25.86	25.52	0	12.4	0.592
4.25	2.25	1.1	18:0	00:23:53	0.039	7.2	26.5	5	25.65	0.039	26.1	26.1	25.65	25.37	0	10.8	0.526
0.25	2.75	1.1	18:0	00:18:05	0.039	10.2	26.5	26	25.56	0.039	26.1	26.1	25.56	25.22	0	10.4	0.506
1.25	2.75	1.1	19:0	01:22:32	0.038	7.4	26.8	36	25.9	0.038	26.4	26.4	25.9	25.59	0	12.6	0.601
2.25	2.75	1.1	19:0	01:55:58	0.04	8.6	26.7	19	25.92	0.04	26.3	26.3	25.92	25.68	0	12.5	0.597
3.25	2.75	1.1	19:0	01:22:32	0.038	7.4	26.8	14	25.9	0.038	26.4	26.4	25.9	25.59	0	12.6	0.601
4.25	2.75	1.1	18:0	00:18:05	0.039	10.2	26.5	4	25.56	0.039	26.1	26.1	25.56	25.22	0	10.4	0.506
0.25	3.25	1.1	17:0	00:12:09	0.04	8.7	26.4	25	25.64	0.04	26	26	25.64	25.41	0	10.6	0.515
1.25	3.25	1.1	19:0	01:28:23	0.04	5	26.7	37	25.91	0.04	26.3	26.3	25.91	25.66	0	12.4	0.595
3.25	3.25	1.1	19:0	01:28:23	0.04	5	26.7	15	25.91	0.04	26.3	26.3	25.91	25.66	0	12.4	0.595
4.25	3.25	1.1	17:0	00:12:09	0.04	8.7	26.4	3	25.64	0.04	26	26	25.64	25.41	0	10.6	0.515
0.25	3.75	1.1	17:0	00:06:03	0.036	18.4	26.4	24	25.61	0.036	26	26	25.61	25.38	0	10.5	0.511
1.25	3.75	1.1	19:0	01:35:25	0.04	0	26.7	38	25.88	0.04	26.3	26.3	25.88	25.61	0	12.3	0.588
2.25	3.75	1.1	19:0	01:49:03	0.039	7.3	26.8	18	25.91	0.039	26.4	26.4	25.91	25.6	0	12.6	0.603
3.25	3.75	1.1	19:0	01:35:25	0.04	0	26.7	16	25.88	0.04	26.3	26.3	25.88	25.61	0	12.3	0.588
4.25	3.75	1.1	17:0	00:06:03	0.036	18.4	26.4	2	25.61	0.036	26	26	25.61	25.38	0	10.5	0.511
0.25	4.25	1.1	17:0	00:00:00	0.04	0	26.4	23	25.58	0.04	26	26	25.58	25.31	0	10.3	0.502
1.25	4.25	1.1	19:0	01:41:54	0.039	7.4	26.7	39	25.94	0.039	26.3	26.3	25.94	25.71	0	12.6	0.601
3.25	4.25	1.1	19:0	01:41:54	0.039	7.4	26.7	17	25.94	0.039	26.3	26.3	25.94	25.71	0	12.6	0.601
4.25	4.25	1.1	17:0	00:00:00	0.04	0	26.4	1	25.58	0.04	26	26	25.58	25.31	0	10.3	0.502
0.25	0.25	1.7	18:0	00:50:12	0.04	22.4	26.9	31		0.041	26.5	26.5		25.4	0	12.4	0.592
1.25	0.25	1.7	18:0	00:57:20	0.041	34.4	27.1	32		0.042	26.7	26.7		26.88	0	19.1	0.818
3.25	0.25	1.7	18:0	00:57:20	0.041	34.4	27.1	10		0.042	26.7	26.7		26.88	0	19.1	0.818
4.25	0.25	1.7	18:0	00:50:12	0.04	22.4	26.9	9		0.041	26.5	26.5		25.4	0	12.4	0.592
0.25	0.75	1.7	18:0	00:42:15	0.038	12.9	27	30		0.039	26.6	26.6		25.51	0	13.1	0.622
1.25	0.75	1.7	18:0	01:03:28	0.039	11.6	26.8	33		0.04	26.4	26.4		26.68	0	16.7	0.744
2.25	0.75	1.7	19:0	02:09:56	0.039	8.9	27.1	21		0.04	26.7	26.7		25.87	0	14.9	0.685
3.25	0.75	1.7	18:0	01:03:28	0.039	11.6	26.8	11		0.04	26.4	26.4		26.68	0	16.7	0.744
4.25	0.75	1.7	18:0	00:42:15	0.038	12.9	27	8		0.039	26.6	26.6		25.51	0	13.1	0.622
0.25	1.25	1.7	18:0	00:36:47	0.037	9.5	27	29		0.038	26.6	26.6		25.3	0	12.4	0.595
4.25	1.25	1.7	18:0	00:36:47	0.037	9.5	27	7		0.038	26.6	26.6		25.3	0	12.4	0.595
0.25	1.75	1.7	18:0	00:29:58	0.036	9.6	26.9	28		0.037	26.5	26.5		25.36	0	12.2	0.587
1.25	1.75	1.7	18:0	01:09:40	0.043	8.2	27	34		0.044	26.6	26.6		26.01	0	15	0.688
2.25	1.75	1.7	19:0	02:02:53	0.032	19	27.2	20		0.033	26.8	26.8		25.86	0	15.3	0.699
3.25	1.75	1.7	18:0	01:09:40	0.043	8.2	27	12		0.044	26.6	26.6		26.01	0	15	0.688
4.25	1.75	1.7	18:0	00:29:58	0.036	9.6	26.9	6		0.037	26.5	26.5		25.36	0	12.2	0.587
0.25	2.25	1.7	18:0	00:23:53	0.037	7.7	26.9	27		0.038	26.5	26.5		25.37	0	12.3	0.588
1.25	2.25	1.7	18:0	01:16:12	0.039	5.2	27	35		0.04	26.6	26.6		25.52	0	13.2	0.624
3.25	2.25	1.7	18:0	01:16:12	0.039	5.2	27	13		0.04	26.6	26.6		25.52	0	13.2	0.624
4.25	2.25	1.7	18:0	00:23:53	0.037	7.7	26.9	5		0.038	26.5	26.5		25.37	0	12.3	0.588
0.25	2.75	1.7	18:0	00:18:05	0.036	13.5	26.8	26		0.037	26.4	26.4		25.22	0	11.4	0.553
1.25	2.75	1.7	19:0	01:22:32	0.034	15.7	27.2	36		0.035	26.8	26.8		25.59	0	14.3	0.664
2.25	2.75	1.7	19:0	01:55:58	0.033	10.6	27	19		0.034	26.6	26.6		25.68	0	13.7	0.645
3.25	2.75	1.7	19:0	01:22:32	0.034	15.7	27.2	14		0.035	26.8	26.8		25.59	0	14.3	0.664
4.25	2.75	1.7	18:0	00:18:05	0.036	13.5	26.8	4		0.037	26.4	26.4		25.22	0	11.4	0.553
0.25	3.25	1.7	17:0	00:12:09	0.034	24	27	25		0.035	26.6	26.6		25.41	0	12.8	0.609
1.25	3.25	1.7	19:0	01:28:23	0.037	15.5	27.2	37		0.038	26.8	26.8		25.66	0	14.5	0.673
3.25	3.25	1.7	19:0	01:28:23	0.037	15.5	27.2	15		0.038	26.8	26.8		25.66	0	14.5	0.673
4.25	3.25	1.7	17:0	00:12:09	0.034	24	27	3		0.035	26.6	26.6		25.41	0	12.8	0.609
0.25	3.75	1.7	17:0	00:06:03	0.04	16	26.9	24		0.041	26.5	26.5		25.38	0	12.3	0.59
1.25	3.75	1.7	19:0	01:35:25	0.038	5.3	26.9	38		0.039	26.5	26.5		25.61	0	13.1	0.62
2.25	3.75	1.7	19:0	01:49:03	0.039	9	26.9	18		0.04	26.5	26.5		25.6	0	13	0.618
3.25	3.75	1.7	19:0	01:35:25	0.038	5.3	26.9	16		0.039	26.5	26.5		25.61	0	13.1	0.62
4.25	3.75	1.7	17:0	00:06:03	0.04	16	26.9	2		0.041	26.5	26.5		25.38	0	12.3	0.59
0.25	4.25	1.7	17:0	00:00:00	0.04	21.8	26.8	23		0.041	26.4	26.4		25.31	0	11.7	0.565
1.25	4.25	1.7	19:0	01:41:54	0.037	9.3	27	39		0.038	26.6	26.6		25.71	0	13.8	0.648
3.25	4.25	1.7	19:0	01:41:54	0.037	9.3	27	17		0.038	26.6	26.6		25.71	0	13.8	0.648
4.25	4.25	1.7	17:0	00:00:00	0.04	21.8	26.8	1		0.041	26.4	26.4		25.31	0	11.7	0.565
0.25	0.25	2.1	18:0	00:50:12	0.039	34.9	26.8	31		0.04	26.6	26.6		25.4	0	12.8	0.608

1.25	0.25	2.1	18:0	00:57:20	0.082	23	26.4	32		0.082	26.2	26.2		26.88	3.5	16.4	0.735
3.25	0.25	2.1	18:0	00:57:20	0.082	23	26.4	10		0.082	26.2	26.2		26.88	3.5	16.4	0.735
4.25	0.25	2.1	18:0	00:50:12	0.039	34.9	26.8	9		0.04	26.6	26.6		25.4	0	12.8	0.608
0.25	0.75	2.1	18:0	00:42:15	0.062	12.9	26.7	30		0.062	26.5	26.5		25.51	1.7	12.7	0.607
1.25	0.75	2.1	18:0	01:03:28	0.042	17.9	26.8	33		0.043	26.6	26.6		26.68	0	17.7	0.776
2.25	0.75	2.1	19:0	02:09:56	0.042	15.2	27.1	21		0.043	26.8	26.8		25.87	0	15.3	0.701
3.25	0.75	2.1	18:0	01:03:28	0.042	17.9	26.8	11		0.043	26.6	26.6		26.68	0	17.7	0.776
4.25	0.75	2.1	18:0	00:42:15	0.062	12.9	26.7	8		0.062	26.5	26.5		25.51	1.7	12.7	0.607
0.25	1.25	2.1	18:0	00:36:47	0.061	16.7	26.6	29		0.061	26.4	26.4		25.3	1.7	11.7	0.564
4.25	1.25	2.1	18:0	00:36:47	0.061	16.7	26.6	7		0.061	26.4	26.4		25.3	1.7	11.7	0.564
0.25	1.75	2.1	18:0	00:29:58	0.056	17.5	26.7	28		0.057	26.5	26.5		25.36	1.2	12.2	0.587
1.25	1.75	2.1	18:0	01:09:40	0.047	8.5	26.9	34		0.048	26.7	26.7		26.01	0	15.4	0.703
2.25	1.75	2.1	19:0	02:02:53	0.04	20.6	26.9	20		0.041	26.7	26.7		25.86	0	14.8	0.684
3.25	1.75	2.1	18:0	01:09:40	0.047	8.5	26.9	12		0.048	26.7	26.7		26.01	0	15.4	0.703
4.25	1.75	2.1	18:0	00:29:58	0.056	17.5	26.7	6		0.057	26.5	26.5		25.36	1.2	12.2	0.587
0.25	2.25	2.1	18:0	00:23:53	0.051	26	26.7	27		0.052	26.5	26.5		25.37	0.5	12.3	0.588
1.25	2.25	2.1	18:0	01:16:12	0.048	25	26.8	35		0.049	26.6	26.6		25.52	0	13.2	0.624
3.25	2.25	2.1	18:0	01:16:12	0.048	25	26.8	13		0.049	26.6	26.6		25.52	0	13.2	0.624
4.25	2.25	2.1	18:0	00:23:53	0.051	26	26.7	5		0.052	26.5	26.5		25.37	0.5	12.3	0.588
0.25	2.75	2.1	18:0	00:18:05	0.049	24.3	26.6	26		0.05	26.4	26.4		25.22	0	11.4	0.553
1.25	2.75	2.1	19:0	01:22:32	0.038	17.3	26.9	36		0.039	26.7	26.7		25.59	0	13.8	0.648
2.25	2.75	2.1	19:0	01:55:58	0.04	26.3	26.9	19		0.041	26.7	26.7		25.68	0	14.2	0.66
3.25	2.75	2.1	19:0	01:22:32	0.038	17.3	26.9	14		0.039	26.7	26.7		25.59	0	13.8	0.648
4.25	2.75	2.1	18:0	00:18:05	0.049	24.3	26.6	4		0.05	26.4	26.4		25.22	0	11.4	0.553
0.25	3.25	2.1	17:0	00:12:09	0.04	30.3	26.8	25		0.041	26.6	26.6		25.41	0	12.8	0.609
1.25	3.25	2.1	19:0	01:28:23	0.045	12.6	26.8	37		0.046	26.6	26.6		25.66	0	13.7	0.642
3.25	3.25	2.1	19:0	01:28:23	0.045	12.6	26.8	15		0.046	26.6	26.6		25.66	0	13.7	0.642
4.25	3.25	2.1	17:0	00:12:09	0.04	30.3	26.8	3		0.041	26.6	26.6		25.41	0	12.8	0.609
0.25	3.75	2.1	17:0	00:06:03	0.038	21.2	26.9	24		0.039	26.7	26.7		25.38	0	13.1	0.621
1.25	3.75	2.1	19:0	01:35:25	0.052	18	26.9	38		0.053	26.7	26.7		25.61	0.7	13.9	0.651
2.25	3.75	2.1	19:0	01:49:03	0.035	18.9	26.9	18		0.036	26.7	26.7		25.6	0	13.9	0.65
3.25	3.75	2.1	19:0	01:35:25	0.052	18	26.9	16		0.053	26.7	26.7		25.61	0.7	13.9	0.651
4.25	3.75	2.1	17:0	00:06:03	0.038	21.2	26.9	2		0.039	26.7	26.7		25.38	0	13.1	0.621
0.25	4.25	2.1	17:0	00:00:00	0.043	16.8	26.8	23		0.044	26.6	26.6		25.31	0	12.5	0.596
1.25	4.25	2.1	19:0	01:41:54	0.046	19.4	26.8	39		0.047	26.6	26.6		25.71	0	13.8	0.648
3.25	4.25	2.1	19:0	01:41:54	0.046	19.4	26.8	17		0.047	26.6	26.6		25.71	0	13.8	0.648
4.25	4.25	2.1	17:0	00:00:00	0.043	16.8	26.8	1		0.044	26.6	26.6		25.31	0	12.5	0.596
0.25	0.25	2.6	18:0	00:50:12	0.049	31.7	27.2	31		0.058	26.5	26.5		25.4	1.5	12.4	0.592
1.25	0.25	2.6	18:0	00:57:20	0.092	24.6	26.8	32		0.102	26.1	26.1		26.88	5.1	14.3	0.666
3.25	0.25	2.6	18:0	00:57:20	0.092	24.6	26.8	10		0.102	26.1	26.1		26.88	5.1	14.3	0.666
4.25	0.25	2.6	18:0	00:50:12	0.049	31.7	27.2	9		0.058	26.5	26.5		25.4	1.5	12.4	0.592
0.25	0.75	2.6	18:0	00:42:15	0.067	25.5	26.8	30		0.077	26.1	26.1		25.51	3.2	11.2	0.544
1.25	0.75	2.6	18:0	01:03:28	0.084	29.8	27.2	33		0.094	26.5	26.5		26.68	4.5	15.9	0.718
2.25	0.75	2.6	19:0	02:09:56	0.043	33.3	27.6	21		0.052	26.9	26.9		25.87	0.6	15.8	0.716
3.25	0.75	2.6	18:0	01:03:28	0.084	29.8	27.2	11		0.094	26.5	26.5		26.68	4.5	15.9	0.718
4.25	0.75	2.6	18:0	00:42:15	0.067	25.5	26.8	8		0.077	26.1	26.1		25.51	3.2	11.2	0.544
0.25	1.25	2.6	18:0	00:36:47	0.059	30.4	26.8	29		0.069	26.1	26.1		25.3	2.6	10.6	0.517
4.25	1.25	2.6	18:0	00:36:47	0.059	30.4	26.8	7		0.069	26.1	26.1		25.3	2.6	10.6	0.517
0.25	1.75	2.6	18:0	00:29:58	0.048	42.3	27	28		0.057	26.3	26.3		25.36	1.5	11.5	0.556
1.25	1.75	2.6	18:0	01:09:40	0.048	31.7	27.6	34		0.057	26.9	26.9		26.01	1.3	16.4	0.735
2.25	1.75	2.6	19:0	02:02:53	0.04	15.9	27.6	20		0.049	26.9	26.9		25.86	0	15.8	0.715
3.25	1.75	2.6	18:0	01:09:40	0.048	31.7	27.6	12		0.057	26.9	26.9		26.01	1.3	16.4	0.735
4.25	1.75	2.6	18:0	00:29:58	0.048	42.3	27	6		0.057	26.3	26.3		25.36	1.5	11.5	0.556
0.25	2.25	2.6	18:0	00:23:53	0.042	24.5	27.1	27		0.051	26.4	26.4		25.37	0.4	11.9	0.573
1.25	2.25	2.6	18:0	01:16:12	0.045	26.6	27.6	35		0.054	26.9	26.9		25.52	0.9	14.4	0.67
3.25	2.25	2.6	18:0	01:16:12	0.045	26.6	27.6	13		0.054	26.9	26.9		25.52	0.9	14.4	0.67
4.25	2.25	2.6	18:0	00:23:53	0.042	24.5	27.1	5		0.051	26.4	26.4		25.37	0.4	11.9	0.573
0.25	2.75	2.6	18:0	00:18:05	0.036	38.2	27.1	26		0.045	26.4	26.4		25.22	0	11.4	0.553
1.25	2.75	2.6	19:0	01:22:32	0.031	32.7	27.6	36		0.04	26.9	26.9		25.59	0	14.7	0.679
2.25	2.75	2.6	19:0	01:55:58	0.034	24.9	27.6	19		0.043	26.9	26.9		25.68	0	15	0.691
3.25	2.75	2.6	19:0	01:22:32	0.031	32.7	27.6	14		0.04	26.9	26.9		25.59	0	14.7	0.679
4.25	2.75	2.6	18:0	00:18:05	0.036	38.2	27.1	4		0.045	26.4	26.4		25.22	0	11.4	0.553
0.25	3.25	2.6	17:0	00:12:09	0.035	22	27.4	25		0.044	26.7	26.7		25.41	0	13.2	0.625
1.25	3.25	2.6	19:0	01:28:23	0.042	18.6	27.8	37		0.051	27.1	27.1		25.66	0.4	15.9	0.72
3.25	3.25	2.6	19:0	01:28:23	0.042	18.6	27.8	15		0.051	27.1	27.1		25.66	0.4	15.9	0.72
4.25	3.25	2.6	17:0	00:12:09	0.035	22	27.4	3		0.044	26.7	26.7		25.41	0	13.2	0.625
0.25	3.75	2.6	17:0	00:06:03	0.03	33.7	27.4	24		0.039	26.7	26.7		25.38	0	13.1	0.621
1.25	3.75	2.6	19:0	01:35:25	0.044	28.4	27.8	38		0.053	27.1	27.1		25.61	0.7	15.7	0.713
2.25	3.75	2.6	19:0	01:49:03	0.046	39.8	27.4	18		0.055	26.7	26.7		25.6	1.1	13.9	0.65
3.25	3.75	2.6	19:0	01:35:25	0.044	28.4	27.8	16		0.053	27.1	27.1		25.61	0.7	15.7	0.713
4.25	3.75	2.6	17:0	00:06:03	0.03	33.7	27.4	2		0.039	26.7	26.7		25.38	0	13.1	0.621
0.25	4.25	2.6	17:0	00:00:00	0.028	39.6	27.5	23		0.037	26.8	26.8		25.31	0	13.3	0.627

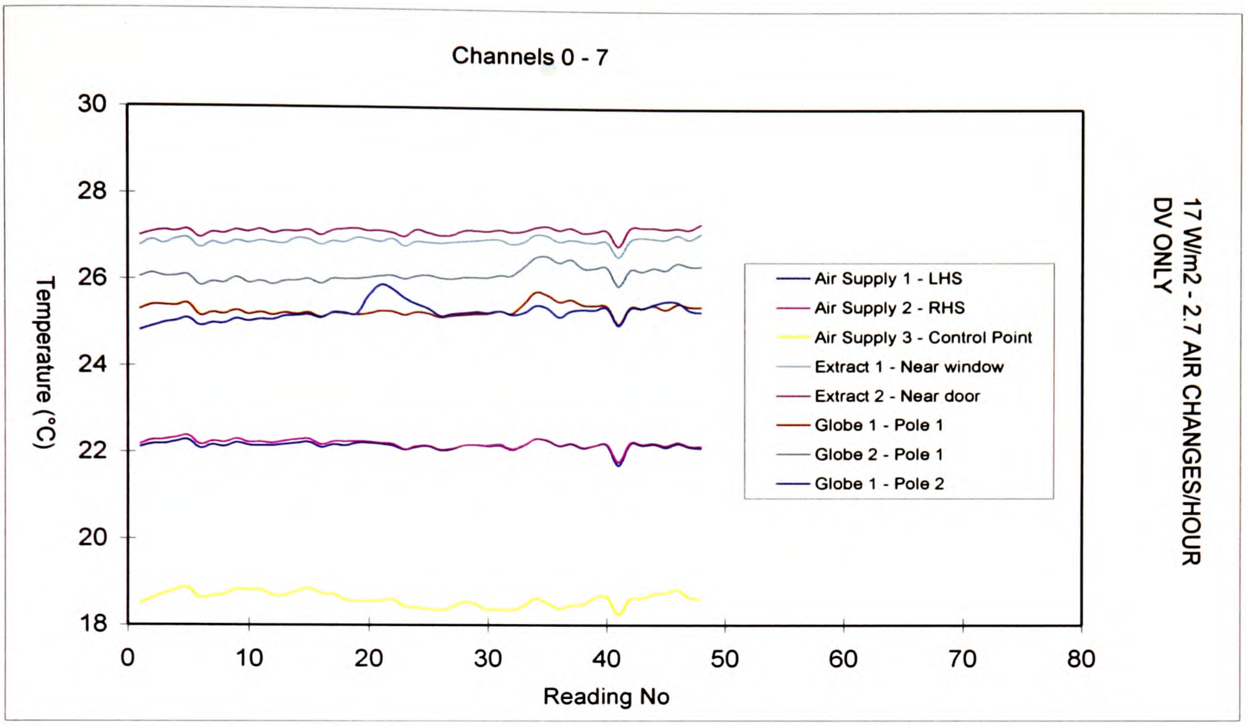
Room Temperature Data (Surface Thermocouples)

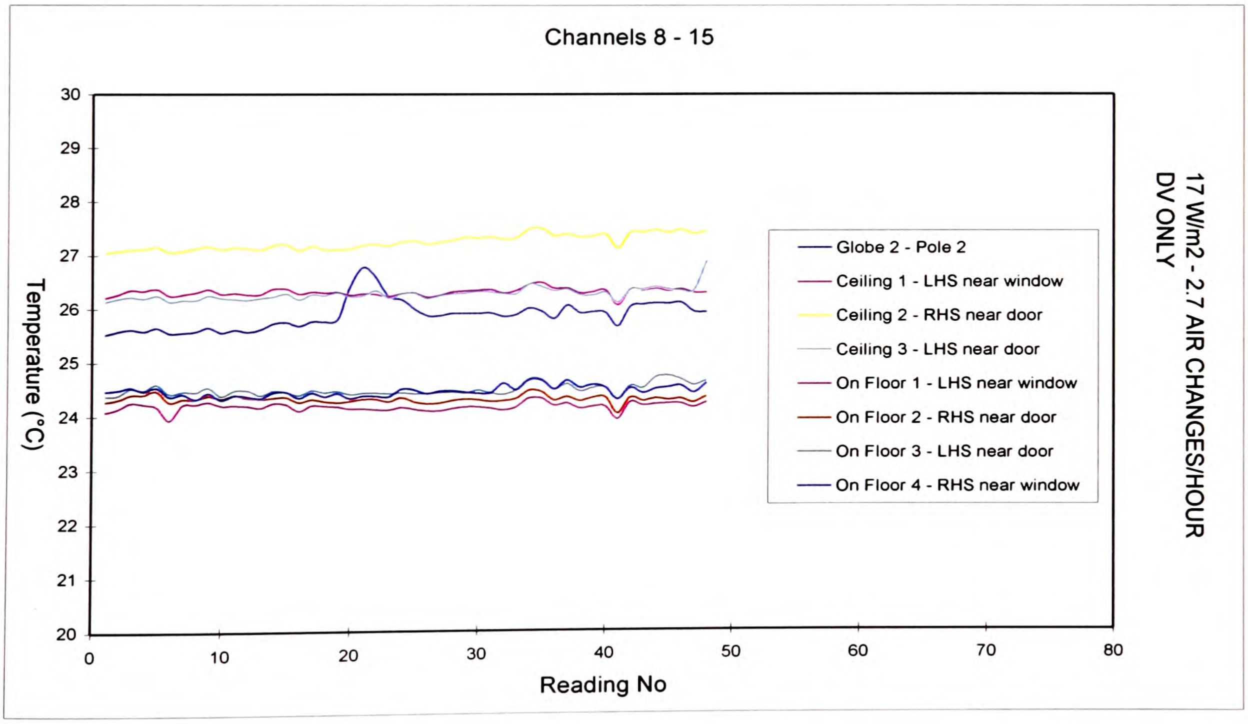
Experiment 1 - 17 W/m^2 with 2.7 air changes per hour

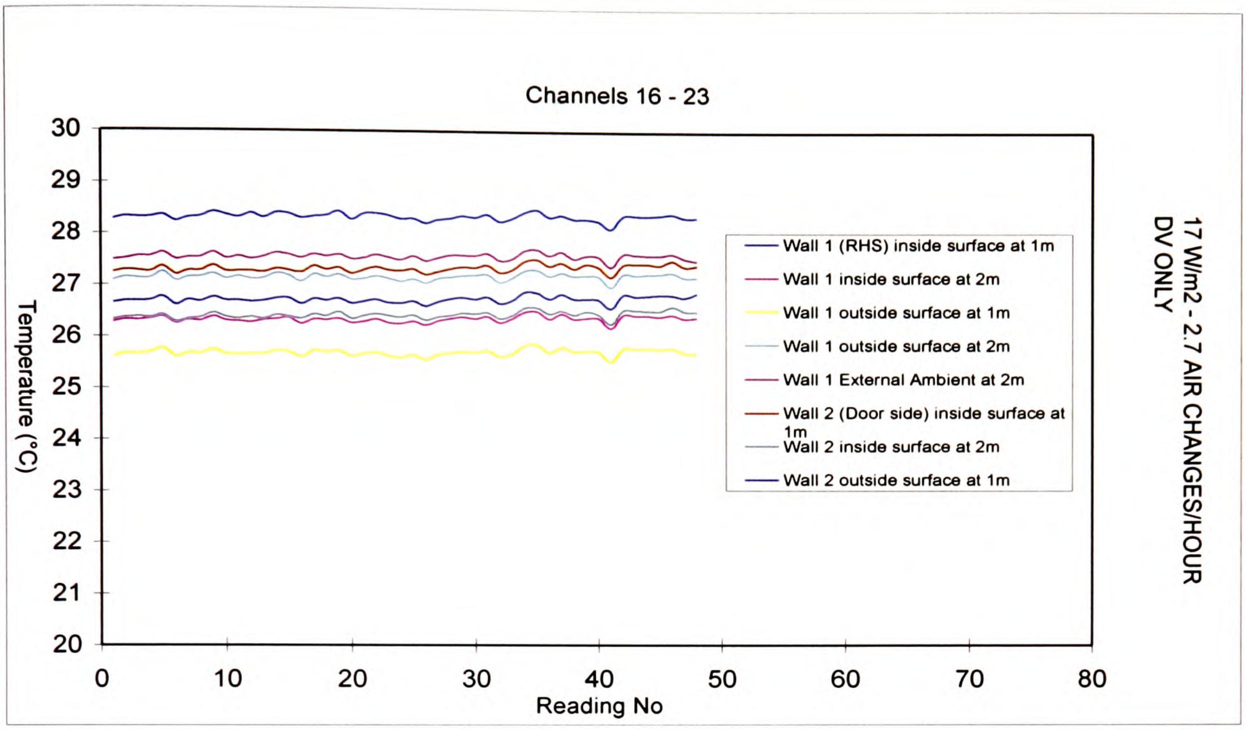
Real time heat loss calculations highlighted in green

Channel	Location	Temp (°C)	A Positive figure indicates flux into the facility				
CH0	Air Supply 1 - LHS	22.13					
CH1	Air Supply 2 - RHS	22.17					
CH2	Air Supply Andrew Geens	18.58	Fluxes	Area	Δ T	U-value	Flux
CH3	Extract 1 - Near w indow	27.11		(m²)	(°C)	(W/m2K)	(W)
CH4	Extract 2 - Near door	27.34					
CH5	Globe 1 - Pole 1	25.41	Floor 1	5.0625	-2.29	0.715	-8.3069
CH6	Globe 2 - Pole 1	26.34	Floor 2	5.0625	-2.58	0.715	-9.3496811
CH7	Globe 1 - Pole 2	25.28	Floor 3	5.0625	-2.77	0.715	-10.014233
CH8	Globe 2 - Pole 2	25.92	Floor 4	5.0625	-2.58	0.715	-9.3496811
CH9	Ceiling 1 - LHS near w indow	26.29	Roof	20.25	0.92	1.21	22.420745
CH10	Ceiling 2 - RHS near door	27.44	Wall 1 @ 2.9m	1.8	-1.18	0.717	-1.5275461
CH11	Ceiling 3 - LHS near door	26.87	Wall 1 @ 2m	12.85	0.77	0.717	7.0720427
CH12	On Floor 1 - LHS near w indow	24.24	Wall 1 average	13.95	0.51	0.717	5.1403628
CH13	On Floor 2 - RHS near door	24.35	Wall 2 @ 2.9m	1.8	0.93	0.717	1.197334
CH14	On Floor 3 - LHS near door	24.64	Wall 2 @ 2m	12.85	1.01	0.717	9.2854301
CH15	On Floor 4 - RHS near w indow	24.58	Wall 2 average	13.95	1.00	0.717	9.9761679
CH16 - Ch0	Wall 1 (RHS) inside surface at 2.9m	26.86	Wall 3 @ 2.9	1.8	0.70	0.717	0.8973703
CH17 - Ch1	Wall 1 inside surface at 2m	26.39	Wall 3 @ 2m	12.85	0.70	0.717	6.442217
CH18 - Ch2	Wall 1 outside surface at 2.9m	25.68	Wall 3 average	13.95	0.70	0.717	6.9886116
CH19 - Ch3	Wall 1 outside surface at 2m	27.16	Wall 4 @ 1m	4.05	0.47	0.402	0.7679417
CH20 - Ch4	Wall 1 External Ambient at 2m	27.50	Wall 4 @ 2m	5.148	-0.03	8.54	-1.416806
CH21 - Ch5	Wall 2 (Door side) inside surface at 2.9m	27.41	Wall 4 @ 2.5 m	4.752	0.17	0.402	0.3208714
CH22 - Ch6	Wall 2 inside surface at 2m	26.50	Wall 4 average	13.95	0.18	3.66	9.3058717
CH23 - Ch7	Wall 2 outside surface at 2.9m	28.34	Beam 1		0.01	0	0
CH24 - Ch8	Wall 2 outside surface at 2m	27.51	Beam 2		0.02	0	0
CH25 - Ch9	Wall 2 External Ambient at 2m	27.59	Beam 3		8.99	0	0
CH26 - Ch10	Wall 3 (LHS) inside surface at 2.9m	26.58	Air		8.15		
CH27 - Ch11	Wall 3 inside surface at 2m	26.17					
CH28 - Ch12	Wall 3 outside surface at 2.9m	27.27					
CH29 - Ch13	Wall 3 outside surface at 2m	26.87					
CH30 - Ch14	Wall 3 External Ambient at 2m	26.45					
CH31 - Ch15	Wall 4 (Window side) inside surface at 1m	26.00					
CH32 - Ch0	Wall 4 inside surface at 2m (glass)	26.46					
CH33 - Ch1	Wall 4 inside surface at 2.5m	26.48					
CH34 - Ch2	Wall 4 outside surface at 1m	26.50					
CH35 - Ch3	Wall 4 outside surface at 2m (glass)	26.43					
CH36 - Ch4	Wall 4 outside surface at 2.5m	26.64					
CH37 - Ch5	Wall 4 External Ambient at 1m	26.62					

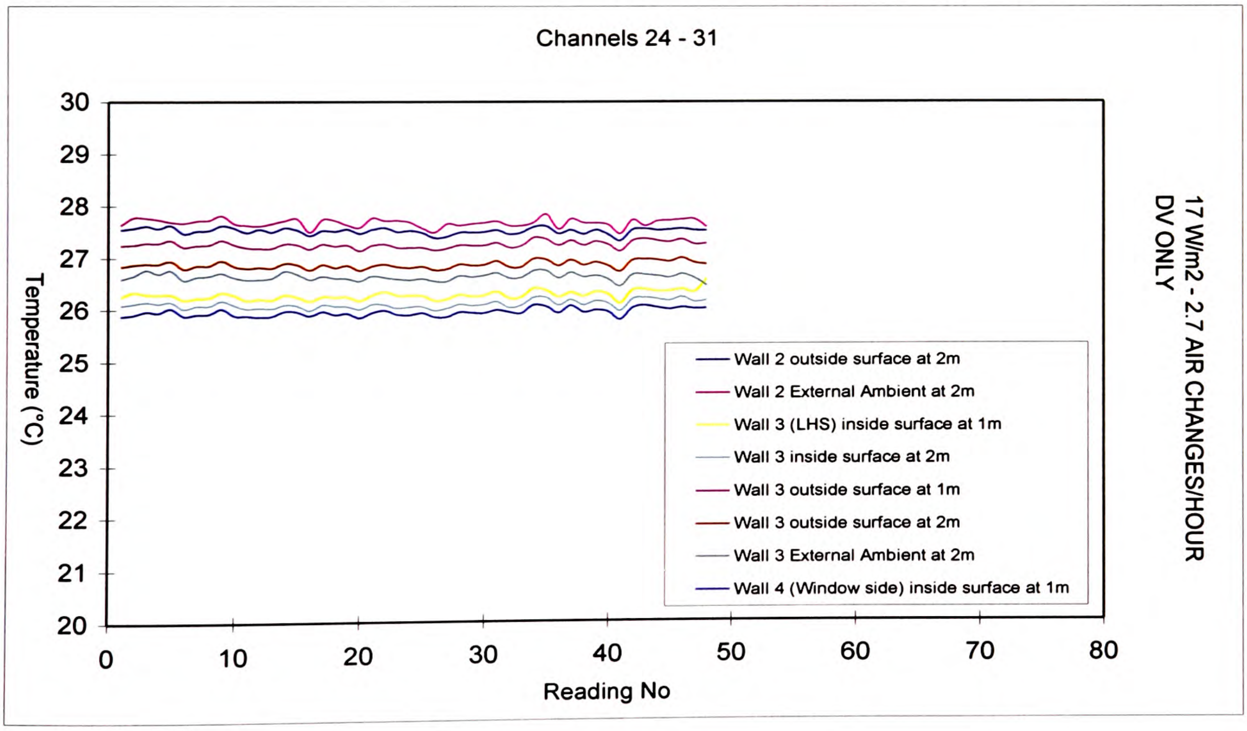
CH38 - Ch6	Wall 4 External Ambient at 2m	26.62					
CH39 - Ch7	Roof Ambient 1	28.01		Heat load			347
CH40 - Ch8	Under Floor 1 - LHS near w indow	21.95					
CH41 - Ch9	Under Floor 2 - RHS near door	21.77		Cooling due to air system			519.31
CH42 - Ch10	Under Floor 3 - LHS near door	21.87					
CH43 - Ch11	Under Floor 4 - RHS near w indow	22.00		Cooling due to w ater system			0
CH44 - Ch12	Ceiling 4 - RHS near w indow	25.71					
CH45 - Ch13	Under Roof 1 - Near w indow	26.61		Overall heat flux from facility			16.811263
CH46 - Ch14	Under Roof 2 - Near door	27.27					
CH47 - Ch15	Roof Ambient 2	27.70		Energy Balance			-155.49874
CH48 - Ch0	Column 1 at 0.01 m	24.33					
CH49 - Ch1	Column 1 at 0.1 m	24.31					
CH50 - Ch2	Column 1 at 0.6 m	25.16		Av Column temps (°C)			
CH51 - Ch3	Column 1 at 1.1 m	25.93		24.263184	0.01		
CH52 - Ch4	Column 1 at 1.7 m	26.48		24.233887	0.1		
CH53 - Ch5	Column 1 at 2.1 m	26.77		25.10498	0.6		
CH54 - Ch6	Column 1 at 2.6 m	26.86		25.848633	1.1		
CH55 - Ch7	Column 1 at 2.69 m	26.83		26.270508	1.7		
CH56 - Ch8	Column 2 at 0.01 m	24.19		26.569336	2.1		
CH57 - Ch9	Column 2 at 0.1 m	24.16		26.770508	2.6		
CH58 - Ch10	Column 2 at 0.6 m	25.05		26.783701	2.69		
CH59 - Ch11	Column 2 at 1.1 m	25.77					
CH60 - Ch12	Column 2 at 1.7 m	26.06		Air flow rate	0.053	m³/s	
CH61 - Ch13	Column 2 at 2.1 m	26.37		Water flow r	0.00E+00	m³/s	
CH62 - Ch14	Column 2 at 2.6 m	26.68		Air Cp	1010	J/kgK	
CH63 - Ch15	Column 2 at 2.69 m	26.73		Water Cp	4180	J/kgK	
CH64 - Ch0 (PRT)	Beam 1 Supply	27.82		Air density	1.19	kg/m³	
CH65 - Ch1 (PRT)	Beam 2 Supply	27.94		Water Dens	1000	kg/m³	
CH66 - Ch2 (PRT)	Beam 3 Supply	19.07					
CH67 - Ch3 (PRT)	Beam 1 Return	27.84					
CH68 - Ch4 (PRT)	Beam 2 Return	27.97					
CH69 - Ch5 (PRT)	Beam 3 Return	28.06					


Channels 0 - 7
Temperature (°C)
30
28
26
24
22
20
18
0
10
20
30
40
50
60
70
80
Reading No
Air Supply 1 - LHS
Air Supply 2 - RHS
Air Supply 3 - Control Point
Extract 1 - Near window
Extract 2 - Near door
Globe 1 - Pole 1
Globe 2 - Pole 1
Globe 1 - Pole 2
17 W/m2 - 2.7 AIR CHANGES/HOUR
DV ONLY

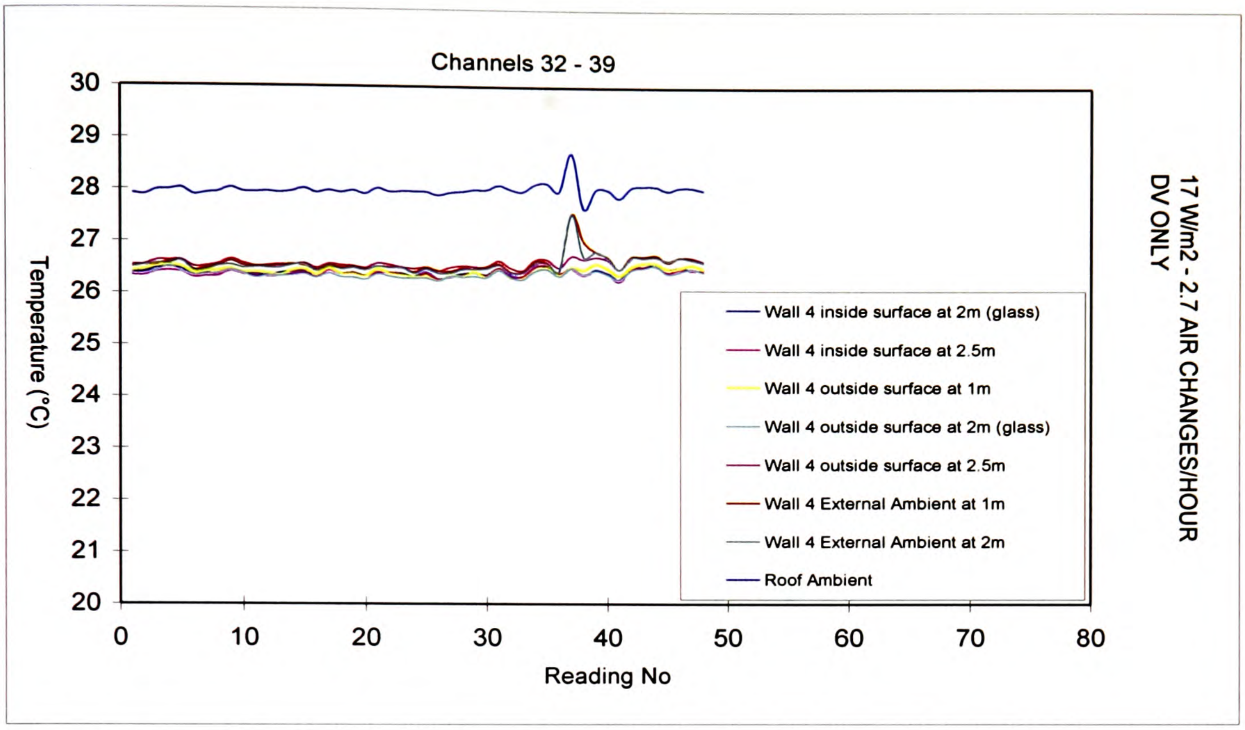

Channels 8 - 15
Temperature (°C)
30
29
28
27
26
25
24
23
22
21
20
0
10
20
30
40
50
60
70
80
Reading No
Globe 2 - Pole 2
Ceiling 1 - LHS near window
Ceiling 2 - RHS near door
Ceiling 3 - LHS near door
On Floor 1 - LHS near window
On Floor 2 - RHS near door
On Floor 3 - LHS near door
On Floor 4 - RHS near window
17 W/m2 - 2.7 AIR CHANGES/HOUR
DV ONLY

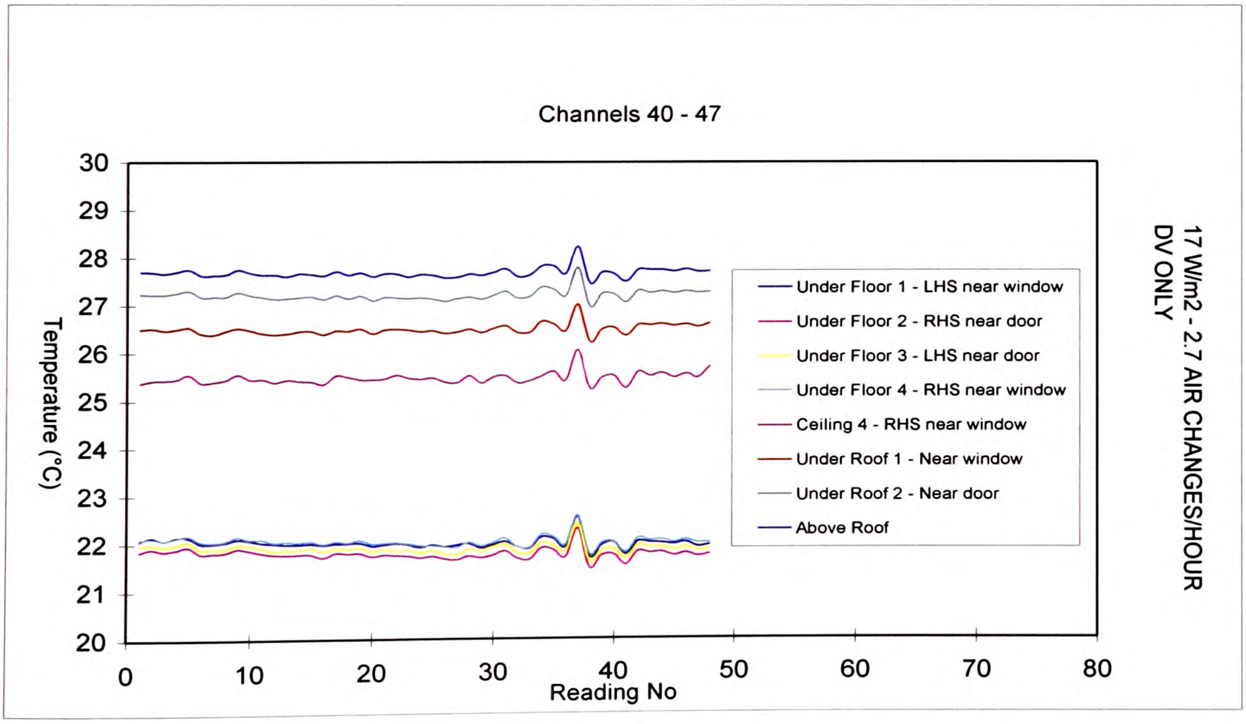


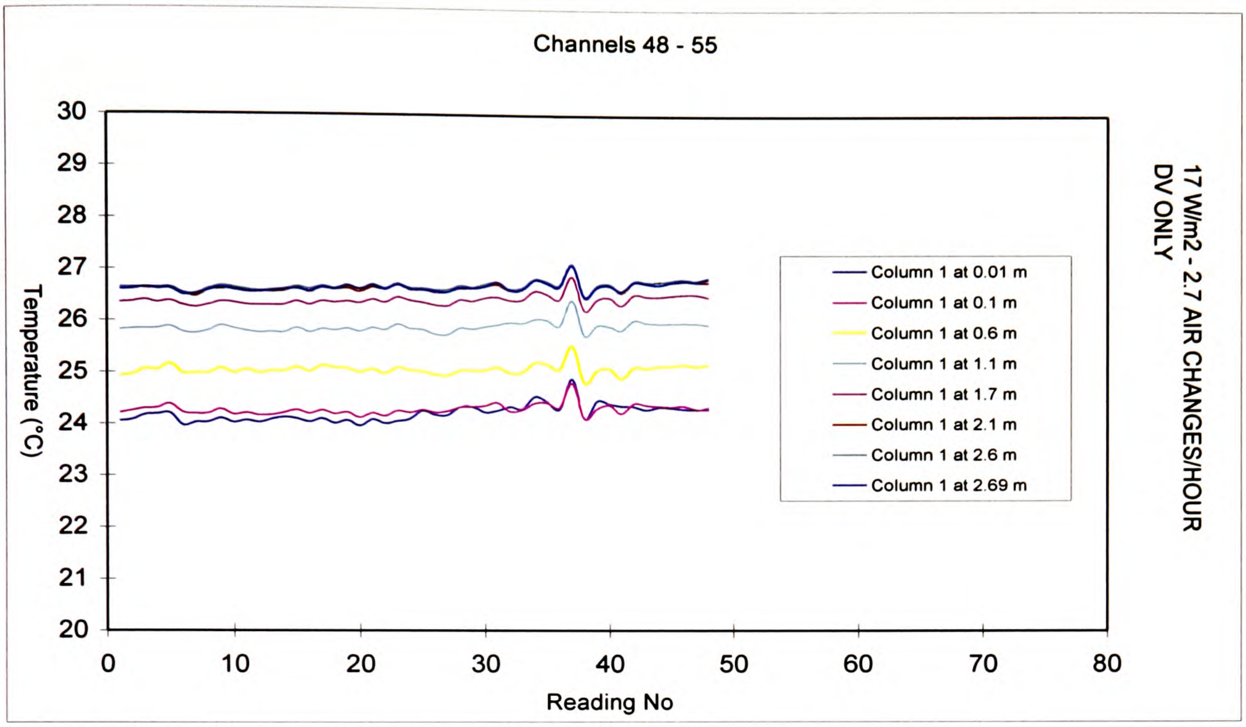
Channels 16 - 23
Temperature (°C)
Reading No
Wall 1 (RHS) inside surface at 1m
Wall 1 inside surface at 2m
Wall 1 outside surface at 1m
Wall 1 outside surface at 2m
Wall 1 External Ambient at 2m
Wall 2 (Door side) inside surface at 1m
Wall 2 inside surface at 2m
Wall 2 outside surface at 1m
17 W/m2 - 2.7 AIR CHANGES/HOUR DV ONLY

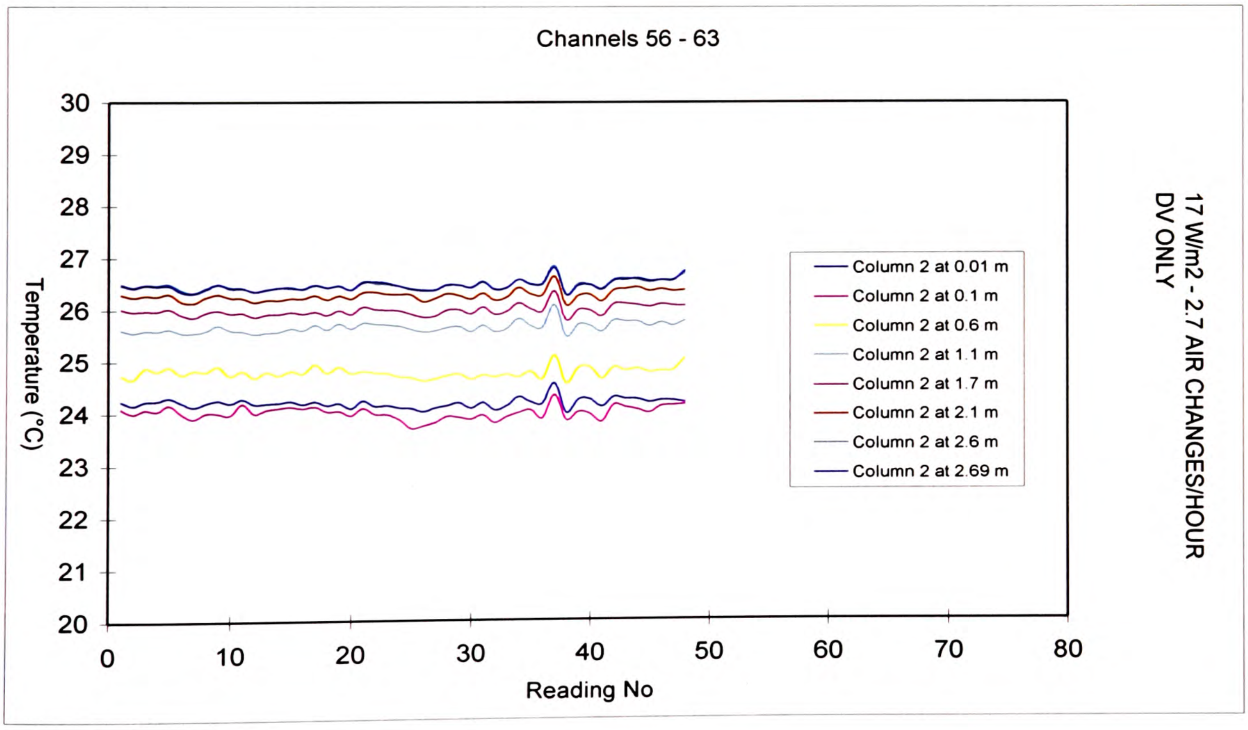


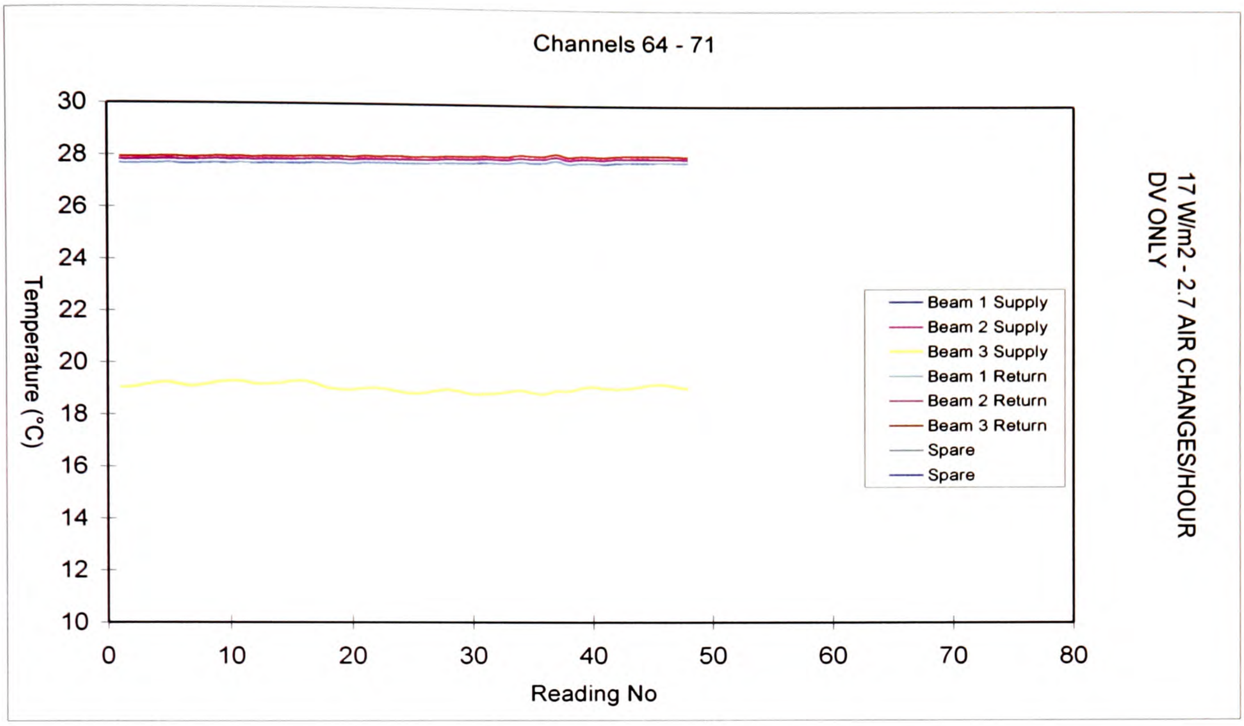
Channels 24 - 31
Temperature (°C)
Reading No
Wall 2 outside surface at 2m
Wall 2 External Ambient at 2m
Wall 3 (LHS) inside surface at 1m
Wall 3 inside surface at 2m
Wall 3 outside surface at 1m
Wall 3 outside surface at 2m
Wall 3 External Ambient at 2m
Wall 4 (Window side) inside surface at 1m
17 W/m2 - 2.7 AIR CHANGES/HOUR DV ONLY


Channels 32 - 39
Temperature (°C)
Reading No
Wall 4 inside surface at 2m (glass)
Wall 4 inside surface at 2.5m
Wall 4 outside surface at 1m
Wall 4 outside surface at 2m (glass)
Wall 4 outside surface at 2.5m
Wall 4 External Ambient at 1m
Wall 4 External Ambient at 2m
Roof Ambient
17 W/m2 - 2.7 AIR CHANGES/HOUR
DV ONLY


Channels 40 - 47
Temperature (°C)
Reading No
Under Floor 1 - LHS near window
Under Floor 2 - RHS near door
Under Floor 3 - LHS near door
Under Floor 4 - RHS near window
Ceiling 4 - RHS near window
Under Roof 1 - Near window
Under Roof 2 - Near door
Above Roof
17 W/m2 - 2.7 AIR CHANGES/HOUR
DV ONLY


Channels 48 - 55
Temperature (°C)
Reading No
Column 1 at 0.01 m
Column 1 at 0.1 m
Column 1 at 0.6 m
Column 1 at 1.1 m
Column 1 at 1.7 m
Column 1 at 2.1 m
Column 1 at 2.6 m
Column 1 at 2.69 m
17 W/m2 - 2.7 AIR CHANGES/HOUR
DV ONLY


Channels 56 - 63
Temperature (°C)
Reading No
Column 2 at 0.01 m
Column 2 at 0.1 m
Column 2 at 0.6 m
Column 2 at 1.1 m
Column 2 at 1.7 m
Column 2 at 2.1 m
Column 2 at 2.6 m
Column 2 at 2.69 m
17 W/m2 - 2.7 AIR CHANGES/HOUR
DV ONLY



Channels 64 - 71
30
28
26
24
22
20
18
16
14
12
10
Temperature (°C)
0
10
20
30
40
50
60
70
80
Reading No
Beam 1 Supply
Beam 2 Supply
Beam 3 Supply
Beam 1 Return
Beam 2 Return
Beam 3 Return
Spare
Spare
17 W/m2 - 2.7 AIR CHANGES/HOUR
DV ONLY

Summary sheet for Room Thermal Comfort Data

Experiment 2 - 53 W/m^2 with 6 air changes per hour

Height	Av.Vel	Max.Vel	Min.Vel	Av.Temp	Max.Temp	Min.Temp	Av.PPD	Max.PPD	Min.PPD	Av.PMV	Max.PMV	Min.PMV
0.1	0.064	0.110926	0.030673	22.7	23.8	21	5.7	6.97	5.01	0.02	0.265	-0.308
0.6	0.047	0.053295	0.041051	24.5	24.9	24	7.4	9.91	6.02	0.33	0.485	0.222
1.1	0.034	0.039995	0.03042	27.1	27.3	26.7	22.08	27.88	17.99	0.9	1.041	0.785
1.7	0.047	0.069264	0.036366	28.9	29.1	28.2	33.56	43.92	25.58	1.16	1.37	0.987
2.1	0.045	0.066648	0.032789	28.9	29.2	28.4	34.11	43.92	28.62	1.17	1.37	1.058
2.6	0.068	0.144215	0.030424	28.6	29.1	28.2	30.83	40.78	25.95	1.11	1.31	0.996
0.1	0.076	0.204124	0.030798	22.2	23.9	19.5	6.66	17.76	5	0.07	0.41	-0.778
0.6	0.039	0.050092	0.032748	24.3	24.5	24.1	6.99	8.64	5.36	0.3	0.429	0.132
1.1	0.042	0.046324	0.039245	27.1	27.5	26.6	21.68	28.62	14.75	0.88	1.058	0.681
1.7	0.042	0.058455	0.033547	28.7	29.1	28.3	31.96	42.81	23.23	1.13	1.349	0.929
2.1	0.048	0.066307	0.038183	28.7	29	28.2	31.92	42.08	22.64	1.13	1.335	0.914
2.6	0.066	0.132371	0.037084	28.9	29.5	28.4	32.49	40.42	25.62	1.14	1.303	0.988
Occ.Zone	0.050333	0.204124	0.03042	24.65	27.5	19.5	11.75167	28.62	5	0.416667	28.62	-0.778
ADPI =	40.21164											
Clo value:	0.6											
Ext.Work:	0											
Humidity:	50											
Met.Rate:	1.2											

Detailed Thermal Comfort Data

Experiment 2 - 53 W/m^2 with 6 air changes per hour

			Test Start Date:		9\8\1996												
			Measurement Time: 180 secs.														
X-Pos (m)	Y-Pos (m)	Height (m)	Time	Rel.Time	Vel	Turb'ce	Temp	Read'g	Globe temp	Corr'd Vel	Corr'd Temp	Shifted Temp	Shifted Globe Temp	Rad Temp	DR	PPD	PMV
0.75	0.25	1.1	10:01	00:51:25	0.041	9.7	27.4	9	26.58	0.03	26.96	27	26.58	26.35	0	18.3	0.795
0.75	0.75	2.6	10:05	00:45:05	0.04	17.5	29.7	8		0.03	29.09	29.1		26.3	0	30.7	1.104
0.75	4.25	0.1	9:020	00:00:00	0.028	30.6	23.2	1		0.031	22.71	22.7		25.78	0	5.01	0.024
3.25	1.75	0.1	10:03	01:14:48	0.034	46	23.6	12		0.031	23.12	23.1		26.34	0	5.54	0.162
0.75	0.75	1.1	10:05	00:45:05	0.042	0	27.4	8	26.55	0.031	26.96	27	26.55	26.3	0	18.1	0.788
0.75	1.75	1.1	9:052	00:32:30	0.042	4.7	27.5	6	26.7	0.031	27.06	27.1	26.7	26.48	0	19.5	0.828
0.75	1.25	1.1	9:059	00:39:11	0.043	4.7	27.4	7	26.68	0.033	26.96	27	26.68	26.5	0	19	0.815
0.75	4.25	1.1	9:020	00:00:00	0.043	4.7	27.1	1	26.76	0.033	26.67	26.7	26.76	26.79	0	18.7	0.806
1.75	1.25	1.1	10:03	01:14:48	0.043	4.7	27.7	12	26.69	0.033	27.25	27.3	26.69	26.34	0	19.9	0.84
0.75	0.25	2.6	10:01	00:51:25	0.042	32.5	29.3	9		0.033	28.71	28.7		26.35	0	28.4	1.053
2.25	0.25	0.6	11:05	02:31:16	0.042	26.6	25.2	22	25.73	0.033	24.55	24.5	25.73	26.43	0	8.44	0.406
0.75	0.25	2.1	10:01	00:51:25	0.031	57.8	29.2	9		0.033	28.82	28.8		26.35	0	29	1.067
3.25	0.75	1.7	10:02	01:07:41	0.033	28.7	29.6	11		0.034	29.11	29.1		27.73	0	40.2	1.299
0.75	2.25	1.1	9:046	00:26:21	0.044	9.2	27.5	5	26.75	0.034	27.06	27.1	26.75	26.55	0	19.8	0.837
0.75	2.75	1.1	9:040	00:20:32	0.044	11.2	27.5	4	27.03	0.034	27.06	27.1	27.03	26.99	0	21.9	0.895
0.75	3.25	1.1	9:033	00:13:32	0.044	13.7	27.6	3	27.04	0.034	27.16	27.2	27.04	26.95	0	22.3	0.905
0.75	3.75	1.1	9:027	00:07:16	0.044	4.6	27.4	2	27.01	0.034	26.96	27	27.01	27.02	0	21.5	0.883
1.75	0.25	1.1	10:01	00:57:42	0.044	2.9	27.3	10	26.58	0.034	26.86	26.9	26.58	26.39	0	18	0.785
1.75	0.75	1.1	10:02	01:07:41	0.044	6.4	27.4	11	26.71	0.034	26.96	27	26.71	26.54	0	19.2	0.82
1.75	1.75	1.1	10:04	01:21:02	0.044	6.5	27.6	13	26.86	0.034	27.16	27.2	26.86	26.66	0	20.9	0.867
2.25	2.25	1.1	11:03	02:18:20	0.044	6.4	27.5	20	27.18	0.034	27.06	27.1	27.18	27.23	0	23.2	0.927
2.25	4.25	1.1	11:02	02:04:14	0.044	7.9	27.6	18	27.32	0.034	27.16	27.2	27.32	27.39	0	24.6	0.964
2.25	3.75	0.6	11:02	02:04:14	0.043	22	25.2	18	25.47	0.034	24.55	24.5	25.47	26.03	0	7.61	0.354
4.25	2.75	0.6	9:040	00:20:32	0.043	11.5	24.9	4	24.79	0.034	24.25	24.2	24.79	25.13	0	5.74	0.189
1.75	2.25	1.1	10:04	01:27:01	0.045	7.8	27.5	14	27	0.035	27.06	27.1	27	26.94	0	21.7	0.888
1.75	4.25	1.1	11:01	01:57:43	0.045	9	27.5	17	27.66	0.035	27.06	27.1	27.66	27.99	0	27.3	1.028
2.25	1.25	1.1	11:04	02:25:20	0.045	0	27.5	1996	27.72	0.035	27.06	27.1	27.72	28.09	0	27.9	1.041
49.25	49.25	1.1	11:05	02:31:16	0.045	6.3	27.4	22	27.58	0.035	26.96	27	27.58	27.92	0	26.3	1.003
2.25	2.25	2.1	11:03	02:18:20	0.034	31.9	29.6	20		0.036	29.21	29.2		27.23	0	37.5	1.245
2.25	3.25	1.1	11:03	02:11:08	0.046	6.1	27.6	19	27.51	0.036	27.16	27.2	27.51	27.7	0	26.3	1.005
4.25	1.25	0.1	9:059	00:39:11	0.039	21.8	22.9	7		0.036	22.43	22.4		26.5	0	5.09	0.065
1.75	1.25	1.7	10:03	01:14:48	0.035	19.8	29.7	12		0.036	29.08	29.1		26.34	0	30.9	1.109
0.75	2.25	2.1	9:046	00:26:21	0.035	20.8	29.6	5		0.037	29.21	29.2		26.55	0	32.9	1.152
3.25	2.75	1.7	10:04	01:27:01	0.036	17.4	29.2	14		0.037	28.72	28.7		26.87	0	31.6	1.123
3.25	3.75	1.7	11:01	01:50:54	0.036	5.5	29.2	16		0.037	28.72	28.7		26.65	0	30.2	1.093

4.25	1.75	1.7	9:052	00:32:30	0.036	11	29.3	6		0.037	28.82	28.8		26.45	0	29.7	1.081
1.75	2.75	1.1	10:05	01:33:21	0.047	6	27.5	15	27.31	0.037	27.06	27.1	27.31	27.44	0	24.3	0.955
3.25	4.25	0.6	11:01	01:57:43	0.046	6.2	25	17	25.44	0.037	24.35	24.3	25.44	26.13	0	7.33	0.335
4.25	0.25	0.6	10:01	00:51:25	0.046	6.2	25.1	9	25.1	0.037	24.45	24.4	25.1	25.52	0	6.54	0.272
4.25	0.75	0.6	10:05	00:45:05	0.046	6.2	25.1	8	24.97	0.037	24.45	24.4	24.97	25.32	0	6.26	0.246
4.25	1.25	0.6	9:059	00:39:11	0.046	6.2	25	7	24.98	0.037	24.35	24.3	24.98	25.39	0	6.19	0.239
4.25	2.25	0.6	9:046	00:26:21	0.046	8.8	25.1	5	24.84	0.037	24.45	24.4	24.84	25.11	0	5.99	0.219
4.25	3.25	0.6	9:033	00:13:32	0.046	6.2	25	3	24.71	0.037	24.35	24.3	24.71	24.96	0	5.7	0.184
4.25	3.75	2.6	9:027	00:07:16	0.028	37.9	29.7	2		0.037	28.96	29		26.02	0	28.4	1.052
0.75	1.25	2.6	9:059	00:39:11	0.046	28.9	29.6	7		0.037	29	29		26.5	0	31.3	1.117
2.25	1.75	0.6	11:03	02:18:20	0.047	18.2	25.1	20	25.85	0.038	24.45	24.4	25.85	26.74	0	8.84	0.429
3.25	2.25	0.6	10:04	01:21:02	0.047	8.6	25.1	13	25.47	0.038	24.45	24.4	25.47	26.13	0	7.56	0.351
3.25	3.25	0.6	10:05	01:33:21	0.047	8.5	25.1	15	25.34	0.038	24.45	24.4	25.34	25.92	0	7.18	0.324
4.25	4.25	0.6	9:020	00:00:00	0.047	0	24.8	1	24.5	0.038	24.15	24.2	24.5	24.68	0	5.36	0.132
2.25	2.75	2.1	11:03	02:11:08	0.037	24.7	29.3	19		0.038	29.01	29		27.48	0	37.7	1.25
1.75	1.25	2.6	10:03	01:14:48	0.047	42.7	29.3	12		0.038	28.71	28.7		26.34	0	28.3	1.051
0.75	2.75	2.1	9:040	00:20:32	0.037	16.1	29.6	4		0.039	29.21	29.2		26.99	0	35.8	1.212
3.25	2.25	1.7	10:04	01:21:02	0.038	13.9	29.2	13		0.039	28.72	28.7		27.08	0	32.9	1.151
2.25	0.75	0.6	11:04	02:25:20	0.048	18.7	24.8	21	25.82	0.039	24.15	24.2	25.82	26.83	0	8.47	0.408
3.25	3.75	0.6	11:01	01:50:54	0.048	2.4	24.9	16	25.37	0.039	24.25	24.2	25.37	26.1	0	7.05	0.314
4.25	3.75	0.6	9:027	00:07:16	0.048	6	24.8	2	24.79	0.039	24.15	24.2	24.79	25.16	0	5.77	0.193
4.25	0.25	2.1	10:01	00:51:25	0.038	47.1	29	9		0.039	28.71	28.7		26.71	0	30.6	1.101
4.25	4.25	2.1	9:020	00:00:00	0.038	31.7	29	1		0.039	28.71	28.7		25.96	0	26.1	1
4.25	0.75	1.1	10:05	00:45:05	0.039	8.9	27.5	8	26.79	0.039	27.11	27.1	26.79	26.6	0	20	0.843
0.75	1.75	2.1	9:052	00:32:30	0.038	37.7	29.3	6		0.04	28.92	28.9		26.48	0	30.5	1.099
3.25	0.25	0.1	10:01	00:57:42	0.042	27.5	23.9	10		0.04	23.41	23.4		26.39	0	5.99	0.219
2.25	0.25	1.7	11:05	02:31:16	0.039	28.2	29.6	22		0.04	29.11	29.1		27.32	0	37.4	1.243
2.25	1.75	1.7	11:03	02:18:20	0.039	13.6	29.6	20		0.04	29.11	29.1		28.1	0	42.8	1.349
2.25	2.75	1.7	11:03	02:11:08	0.039	17.2	29.4	19		0.04	28.92	28.9		27.48	0	37	1.235
3.25	4.25	1.7	11:01	01:57:43	0.039	25.4	29.2	17		0.04	28.72	28.7		26.61	0	30	1.088
4.25	0.75	1.7	10:05	00:45:05	0.039	16.4	29.2	8		0.04	28.72	28.7		26.6	0	29.9	1.086
4.25	2.25	1.7	9:046	00:26:21	0.039	40.2	29	5		0.04	28.52	28.5		26.26	0	26.6	1.011
3.25	1.75	0.6	10:03	01:14:48	0.049	10	25.1	12	25.44	0.04	24.45	24.4	25.44	26.1	0	7.51	0.347
3.25	2.75	0.6	10:04	01:27:01	0.049	8.2	25.1	14	25.4	0.04	24.45	24.4	25.4	26.03	0	7.38	0.338
4.25	1.75	0.6	9:052	00:32:30	0.049	5.8	24.9	6	24.94	0.04	24.25	24.2	24.94	25.41	0	6.06	0.226
1.75	3.75	1.1	11:01	01:50:54	0.05	24	27.3	16	27.73	0.04	26.86	26.9	27.73	28.25	0	27.4	1.031
3.25	3.75	1.1	11:01	01:50:54	0.04	0	27.2	16	26.71	0.04	26.81	26.8	26.71	26.65	0	18.6	0.803
4.25	0.25	1.1	10:01	00:51:25	0.04	7	27.6	9	26.9	0.04	27.21	27.2	26.9	26.71	0	21.1	0.874
4.25	1.25	1.1	9:059	00:39:11	0.04	7.1	27.6	7	26.86	0.04	27.21	27.2	26.86	26.64	0	20.8	0.864
4.25	1.75	1.1	9:052	00:32:30	0.04	5	27.6	6	26.74	0.04	27.21	27.2	26.74	26.45	0	19.9	0.839
4.25	2.75	1.1	9:040	00:20:32	0.04	8.6	27.4	4	26.43	0.04	27.01	27	26.43	26.07	0	17.1	0.758
4.25	3.25	1.1	9:033	00:13:32	0.04	7.1	27.4	3	26.31	0.04	27.01	27	26.31	25.87	0	16.3	0.732
4.25	3.75	1.1	9:027	00:07:16	0.04	8.7	27.3	2	26.36	0.04	26.91	26.9	26.36	26.02	0	16.4	0.736
4.25	4.25	1.1	9:020	00:00:00	0.04	7	27	1	26.21	0.04	26.62	26.6	26.21	25.96	0	14.8	0.681
1.75	1.75	0.1	10:04	01:21:02	0.038	41.3	24.2	13		0.04	23.69	23.7		25.58	0	5.56	0.165
1.75	2.25	0.1	10:04	01:27:01	0.038	18.1	24.3	14		0.04	23.78	23.8		25.77	0	5.88	0.206
1.75	0.75	2.1	10:02	01:07:41	0.039	23	29.4	11		0.041	29.01	29		26.54	0	31.5	1.122
2.25	3.25	2.1	11:03	02:11:08	0.039	19.1	29.6	19		0.041	29.21	29.2		27.7	0	40.7	1.309
2.25	3.75	1.7	11:02	02:04:14	0.04	11.3	29.3	18		0.041	28.82	28.8		26.87	0	32.3	1.138
3.25	3.25	1.7	10:05	01:33:21	0.04	14.2	29.2	15		0.041	28.72	28.7		26.72	0	30.7	1.103
0.75	1.75	0.6	9:052	00:32:30	0.037	19.3	25.1	6	25.1	0.041	24.64	24.6	25.1	25.42	0	6.77	0.292
4.25	3.75	2.1	9:027	00:07:16	0.04	55	28.5	2		0.041	28.22	28.2		26.02	0	23.4	0.934
2.25	2.75	1.1	11:03	02:11:08	0.041	9.8	27.6	19	27.37	0.041	27.21	27.2	27.37	27.48	0	25.1	0.976
3.25	0.25	1.1	10:01	00:57:42	0.041	21.7	27.2	10	27.56	0.041	26.81	26.8	27.56	28.05	0	25.6	0.988
3.25	4.25	1.1	11:01	01:57:43	0.041	6.9	27.5	17	26.8	0.041	27.11	27.1	26.8	26.61	0	20.1	0.845
4.25	2.25	1.1	9:046	00:26:21	0.041	6.9	27.4	5	26.55	0.041	27.01	27	26.55	26.26	0	17.9	0.783
1.75	1.25	2.1	10:03	01:14:48	0.04	8.6	29.6	12		0.041	29.21	29.2		26.34	0	31.6	1.124
2.25	0.75	1.7	11:04	02:25:20	0.041	30.6	29.4	21		0.042	28.92	28.9		27.79	0	39.1	1.277
3.25	0.25	1.7	10:01	00:57:42	0.041	25.6	29.3	10		0.042	28.82	28.8		28.05	0	40.2	1.298
4.25	1.25	1.7	9:059	00:39:11	0.041	16	29.2	7		0.042	28.72	28.7		26.64	0	30.2	1.092
4.25	4.25	1.7	9:020	00:00:00	0.041	25.2	29	1		0.042	28.52	28.5		25.96	0	24.9	0.971
2.25	3.75	2.1	11:02	02:04:14	0.041	11.8	29.2	18		0.042	28.91	28.9		26.87	0	32.9	1.152
2.25	3.25	0.6	11:03	02:11:08	0.038	14.9	25.1	19	25.67	0.042	24.64	24.6	25.67	26.36	0	8.56	0.413
4.25	0.25	2.6	10:01	00:51:25	0.033	42.5	30	9		0.042	29.25	29.3		26.71	0	34.7	1.189
4.25	4.25	2.6	9:020	00:00:00	0.033	36.9	29.7	1		0.042	28.96	29		25.96	0	28	1.043

0.75	0.25	1.7	10:01	00:51:25	0.041	27.1	29.3	9		0.042	28.69	28.7		26.35	0	28.4	1.053
0.75	3.25	1.7	9:033	00:13:32	0.041	29.2	29.6	3		0.042	28.98	29		26.95	0	34.2	1.178
0.75	3.75	1.7	9:027	00:07:16	0.041	15.5	29.4	2		0.042	28.79	28.8		27.02	0	33.2	1.158
1.75	0.75	1.7	10:02	01:07:41	0.041	17.7	29.6	11		0.042	28.98	29		26.54	0	31.5	1.122
2.25	3.25	1.7	11:03	02:11:08	0.041	17.8	29.7	19		0.042	29.08	29.1		27.7	0	40	1.295
0.75	3.25	0.1	9:033	00:13:32	0.04	40.2	22.2	3		0.042	21.73	21.7		25.36	0	5.8	-0.2
2.25	3.75	1.1	11:02	02:04:14	0.042	6.7	27.6	18	27	0.042	27.21	27.2	27	26.87	0	21.9	0.895
3.25	0.75	1.1	10:02	01:07:41	0.042	19.5	27.8	11	27.6	0.042	27.41	27.4	27.6	27.73	0	27.8	1.04
3.25	2.75	1.1	10:04	01:27:01	0.042	4.7	27.6	14	27	0.042	27.21	27.2	27	26.87	0	21.9	0.895
3.25	3.25	1.1	10:05	01:33:21	0.042	8.2	27.5	15	26.87	0.042	27.11	27.1	26.87	26.72	0	20.6	0.859
4.25	0.25	1.7	10:01	00:51:25	0.042	26.6	29.1	9		0.043	28.62	28.6		26.71	0	29.9	1.086
0.75	0.75	0.6	10:05	00:45:05	0.039	14.4	24.9	8	24.98	0.043	24.44	24.4	24.98	25.36	0	6.31	0.251
0.75	1.25	0.6	9:059	00:39:11	0.039	10.2	25.1	7	25.05	0.043	24.64	24.6	25.05	25.35	0	6.66	0.283
1.75	0.25	0.6	10:01	00:57:42	0.039	16.3	24.5	10	24.95	0.043	24.05	24.1	24.95	25.51	0	6.02	0.222
0.75	2.25	1.7	9:046	00:26:21	0.042	25.9	29.6	5		0.043	28.98	29		26.55	0	31.6	1.123
2.25	0.25	1.1	11:05	02:31:16	0.043	6.6	27.6	22	27.27	0.043	27.21	27.2	27.27	27.32	0	24.2	0.954
3.25	2.25	1.1	10:04	01:21:02	0.043	6.7	27.8	13	27.21	0.043	27.41	27.4	27.21	27.08	0	24.2	0.954
3.25	1.75	1.7	10:03	01:14:48	0.043	9.3	29.4	12		0.044	28.92	28.9		27.37	0	36.2	1.22
3.25	0.75	2.1	10:02	01:07:41	0.043	34.9	29.2	11		0.044	28.91	28.9		27.73	0	38.7	1.269
0.75	2.75	1.7	9:040	00:20:32	0.043	13.3	29.6	4		0.044	28.98	29		26.99	0	34.4	1.183
1.75	1.75	1.7	10:04	01:21:02	0.043	15.5	29.6	13		0.044	28.98	29		26.66	0	32.3	1.138
0.75	0.25	0.6	10:01	00:51:25	0.04	10.1	24.9	9	25.01	0.044	24.44	24.4	25.01	25.42	0	6.39	0.259
0.75	4.25	0.6	9:020	00:00:00	0.04	11.3	24.9	1	25.23	0.044	24.44	24.4	25.23	25.78	0	6.95	0.306
4.25	3.25	2.6	9:033	00:13:32	0.035	41.1	29.4	3		0.044	28.67	28.7		25.87	0	25.6	0.988
2.25	1.75	1.1	11:03	02:18:20	0.044	0	27.6	20	27.74	0.044	27.21	27.2	27.74	28.1	0	28.6	1.058
3.25	1.75	1.1	10:03	01:14:48	0.044	8	27.9	12	27.42	0.044	27.51	27.5	27.42	27.37	0	26.5	1.008
1.75	2.25	2.1	10:04	01:27:01	0.043	17.5	29.5	14		0.044	29.11	29.1		26.94	0	34.8	1.191
2.25	0.25	2.1	11:05	02:31:16	0.044	44.5	29.1	22		0.045	28.81	28.8		27.32	0	35.2	1.199
2.25	0.75	2.1	11:04	02:25:20	0.044	23.5	29.2	21		0.045	28.91	28.9		27.79	0	39.1	1.277
3.25	3.25	2.1	10:05	01:33:21	0.044	19.1	29.1	15		0.045	28.81	28.8		26.72	0	31.3	1.117
4.25	2.25	2.1	9:046	00:26:21	0.044	14.4	29.1	5		0.045	28.81	28.8		26.26	0	28.5	1.055
4.25	2.75	2.1	9:040	00:20:32	0.044	23.9	28.8	4		0.045	28.52	28.5		26.07	0	25.5	0.985
3.25	0.75	0.6	10:02	01:07:41	0.054	36.4	24.9	11	25.52	0.045	24.25	24.2	25.52	26.41	0	7.61	0.354
1.75	3.75	1.7	11:01	01:50:54	0.044	19.5	29.7	16		0.045	29.08	29.1		28.25	0	43.9	1.37
2.25	2.25	1.7	11:03	02:18:20	0.044	9	29.6	20		0.045	28.98	29		27.23	0	36	1.216
0.75	0.75	2.1	10:05	00:45:05	0.044	23.1	29.2	8		0.045	28.82	28.8		26.3	0	28.7	1.06
1.75	3.75	2.1	11:01	01:50:54	0.044	14.3	29.5	16		0.045	29.11	29.1		28.25	0	43.9	1.37
2.25	1.25	2.1	11:04	02:25:20	0.044	26.7	29.5	21		0.045	29.11	29.1		26.95	0	34.9	1.192
49.25	49.25	2.1	11:05	02:31:16	0.044	26.5	29.4	22		0.045	29.01	29		27.92	0	40.8	1.31
2.25	1.75	2.1	11:03	02:18:20	0.045	16.5	29.3	20		0.046	29.01	29		28.1	0	42.1	1.335
3.25	3.75	2.1	11:01	01:50:54	0.045	26.7	29.2	16		0.046	28.91	28.9		26.65	0	31.5	1.122
2.25	2.75	0.6	11:03	02:11:08	0.055	21.8	24.7	19	25.71	0.046	24.05	24.1	25.71	26.8	0	8.14	0.388
1.75	2.25	0.6	10:04	01:27:01	0.042	30.2	25.2	14	25.34	0.046	24.73	24.7	25.34	25.77	0	7.59	0.353
1.75	2.75	0.6	10:05	01:33:21	0.042	23.9	25.3	15	25.47	0.046	24.83	24.8	25.47	25.93	0	8.17	0.39
1.75	4.25	0.6	11:01	01:57:43	0.042	16.4	25.4	17	25.67	0.046	24.93	24.9	25.67	26.19	0	9.02	0.439
2.25	4.25	0.6	11:02	02:04:14	0.042	14.2	25.2	18	25.61	0.046	24.73	24.7	25.61	26.23	0	8.56	0.413
2.25	0.75	1.1	11:04	02:25:20	0.046	6.2	27.7	21	27.59	0.046	27.31	27.3	27.59	27.79	0	27.5	1.033
1.75	2.75	1.7	10:05	01:33:21	0.046	16.3	29.7	15		0.047	29.08	29.1		27.44	0	38.2	1.259
49.25	49.25	1.7	11:05	02:31:16	0.046	19.7	29.7	22		0.047	29.08	29.1		27.92	0	41.6	1.325
1.75	0.25	0.1	10:01	00:57:42	0.045	43.8	23.8	10		0.047	23.29	23.3		25.51	0	5.17	0.09
0.75	1.75	2.6	9:052	00:32:30	0.055	25.8	29.1	6		0.047	28.51	28.5		26.48	0	27.9	1.041
0.75	3.25	0.6	9:033	00:13:32	0.043	4.6	25.2	3	25.09	0.047	24.73	24.7	25.09	25.36	0	6.87	0.3
0.75	3.75	0.6	9:027	00:07:16	0.043	9.3	25.1	2	25.26	0.047	24.64	24.6	25.26	25.71	0	7.25	0.329
2.25	2.25	0.6	11:03	02:18:20	0.043	12.4	25.2	20	25.94	0.047	24.73	24.7	25.94	26.79	0	9.91	0.485
0.75	4.25	2.1	9:020	00:00:00	0.046	25.2	29.2	1		0.047	28.82	28.8		26.79	0	31.8	1.127
1.75	1.75	2.1	10:04	01:21:02	0.046	18.6	29.4	13		0.047	29.01	29		26.66	0	32.3	1.138
1.75	2.75	2.1	10:05	01:33:21	0.046	23.2	29.5	15		0.047	29.11	29.1		27.44	0	38.2	1.259
0.75	2.75	0.6	9:040	00:20:32	0.044	9.2	24.9	4	25	0.048	24.44	24.4	25	25.42	0	6.39	0.259
1.75	1.75	0.6	10:04	01:21:02	0.044	6.4	25.2	13	25.22	0.048	24.73	24.7	25.22	25.58	0	7.24	0.328
0.75	1.25	2.1	9:059	00:39:11	0.047	19.8	29.2	7		0.048	28.82	28.8		26.5	0	30	1.088
3.25	2.75	2.1	10:04	01:27:01	0.048	22.8	29.1	14		0.049	28.81	28.8		26.87	0	32.3	1.138
4.25	3.25	2.1	9:033	00:13:32	0.048	48.5	28.5	3		0.049	28.22	28.2		25.87	0	22.6	0.914
0.75	4.25	1.7	9:020	00:00:00	0.048	29.9	29.2	1		0.049	28.59	28.6		26.79	0	30.4	1.097
2.25	1.25	1.7	11:04	02:25:20	0.048	19.5	29.6	21		0.049	28.98	29		26.95	0	34.2	1.178
0.75	2.25	0.6	9:046	00:26:21	0.045	8.9	25.2	5	25.06	0.049	24.73	24.7	25.06	25.31	0	6.8	0.294

1.75	0.75	0.6	10:02	01:07:41	0.045	8.9	25.1	11	25.09	0.049	24.64	24.6	25.09	25.43	0	6.78	0.293
1.75	1.25	0.6	10:03	01:14:48	0.045	10.8	25.2	12	25.15	0.049	24.73	24.7	25.15	25.47	0	7.05	0.314
1.75	3.75	0.6	11:01	01:50:54	0.045	22.9	24.9	16	25.52	0.049	24.44	24.4	25.52	26.31	0	7.91	0.374
0.75	3.75	2.1	9:027	00:07:16	0.048	22.9	29	2		0.049	28.62	28.6		27.02	0	31.8	1.128
1.75	0.25	2.1	10:01	00:57:42	0.048	36.8	29.1	10		0.049	28.72	28.7		26.39	0	28.6	1.058
2.25	4.25	2.1	11:02	02:04:14	0.048	33.6	29.2	18		0.049	28.82	28.8		27.39	0	35.6	1.208
3.25	3.25	2.6	10:05	01:33:21	0.04	35.4	30.1	15		0.049	29.35	29.3		26.72	0	34.8	1.19
3.25	1.75	2.1	10:03	01:14:48	0.049	17.5	29.3	12		0.05	29.01	29		27.37	0	37	1.235
0.75	1.75	1.7	9:052	00:32:30	0.049	19	29	6		0.05	28.4	28.4		26.48	0	27.2	1.026
3.25	0.25	0.6	10:01	00:57:42	0.059	20.8	24.7	10	25.32	0.05	24.05	24.1	25.32	26.18	0.1	6.97	0.308
2.25	2.75	2.6	11:03	02:11:08	0.041	29	30	19		0.05	29.25	29.3		27.48	0.1	40	1.294
4.25	1.75	2.6	9:052	00:32:30	0.041	26.1	29.6	6		0.05	28.86	28.9		26.45	0.1	30.3	1.095
0.75	2.25	2.6	9:046	00:26:21	0.058	26.5	29.1	5		0.051	28.51	28.5		26.55	0.2	28.3	1.05
3.25	2.25	2.1	10:04	01:21:02	0.05	17.9	29.3	13		0.051	29.01	29		27.08	0.2	35.1	1.196
1.75	0.25	1.7	10:01	00:57:42	0.05	24.2	29.3	10		0.051	28.69	28.7		26.39	0.2	28.6	1.058
4.25	3.75	1.7	9:027	00:07:16	0.05	27.4	28.8	2		0.051	28.33	28.3		26.02	0.3	24	0.949
0.75	2.75	2.6	9:040	00:20:32	0.059	30.3	29.3	4		0.052	28.71	28.7		26.99	0.4	32.3	1.139
1.75	2.25	1.7	10:04	01:27:01	0.051	11.2	29.6	14		0.052	28.98	29		26.94	0.3	34.1	1.176
1.75	4.25	2.1	11:01	01:57:43	0.051	28.4	29.2	17		0.052	28.82	28.8		27.99	0.4	39.8	1.29
2.25	1.25	0.6	11:04	02:25:20	0.048	29.1	24.4	21	25.71	0.052	23.96	24	25.71	26.95	0.9	8.17	0.39
4.25	2.25	2.6	9:046	00:26:21	0.043	27.2	29.6	5		0.052	28.86	28.9		26.26	0.4	29.2	1.07
3.25	0.25	2.1	10:01	00:57:42	0.052	29.6	28.8	10		0.053	28.52	28.5		28.05	0.5	37.9	1.253
2.25	1.25	2.6	11:04	02:25:20	0.06	30.4	29.5	21		0.053	28.9	28.9		26.95	0.5	33.5	1.163
49.25	49.25	2.6	11:05	02:31:16	0.06	28.4	29.6	22		0.053	29	29		27.92	0.5	40.8	1.31
2.25	1.75	0.1	11:03	02:18:20	0.054	21.7	24.4	20		0.053	23.91	23.9		27.23	0.9	8.5	0.41
3.25	0.75	0.1	10:02	01:07:41	0.054	27.2	24	11		0.053	23.51	23.5		26.54	1	6.35	0.255
1.75	4.25	1.7	11:01	01:57:43	0.052	23.9	29.4	17		0.053	28.79	28.8		27.99	0.5	39.8	1.29
2.25	3.25	0.1	11:03	02:11:08	0.051	31.6	23.4	19		0.053	22.9	22.9		26.36	1.1	5.36	0.132
49.25	49.25	0.6	11:05	02:31:16	0.049	28.8	24.4	22	25.52	0.053	23.96	24	25.52	26.63	1.1	7.53	0.349
4.25	1.25	2.6	9:059	00:39:11	0.044	36.5	29.6	7		0.053	28.86	28.9		26.64	0.6	31.5	1.121
0.75	0.75	1.7	10:05	00:45:05	0.053	28.5	29.2	8		0.054	28.59	28.6		26.3	0.6	27.4	1.031
2.25	4.25	1.7	11:02	02:04:14	0.053	27.3	29.3	18		0.054	28.69	28.7		27.39	0.6	34.9	1.193
2.25	4.25	0.1	11:02	02:04:14	0.052	36.8	24.3	18		0.054	23.78	23.8		26.23	1.3	6.46	0.265
1.75	2.75	0.1	10:05	01:33:21	0.053	33	23.6	15		0.055	23.1	23.1		25.93	1.5	5.25	0.11
0.75	3.25	2.6	9:033	00:13:32	0.062	36.6	29.3	3		0.055	28.71	28.7		26.95	0.8	32.1	1.134
2.25	2.25	0.1	11:03	02:18:20	0.054	28.3	23.6	20		0.056	23.1	23.1		26.79	1.7	6	0.22
4.25	2.75	2.6	9:040	00:20:32	0.047	28	29.3	4		0.056	28.57	28.6		26.07	0.9	26.1	1
4.25	1.75	2.1	9:052	00:32:30	0.056	16.7	28.8	6		0.057	28.52	28.5		26.45	0.9	27.7	1.037
4.25	3.25	1.7	9:033	00:13:32	0.056	25.7	28.8	3		0.057	28.33	28.3		25.87	1	23.2	0.929
4.25	0.75	2.6	10:05	00:45:05	0.049	29.1	29.4	8		0.058	28.67	28.7		26.6	1	29.9	1.086
4.25	2.75	1.7	9:040	00:20:32	0.057	25.1	28.8	4		0.058	28.33	28.3		26.07	1.1	24.3	0.956
3.25	2.75	2.6	10:04	01:27:01	0.05	29.1	30.3	14		0.059	29.54	29.5		26.87	0.9	36.6	1.227
0.75	3.75	0.1	9:027	00:07:16	0.058	25.8	22.4	2		0.06	21.92	21.9		25.71	2.5	5.29	-0.12
2.25	2.75	0.1	11:03	02:11:08	0.061	19.7	23.2	19		0.06	22.73	22.7		27.7	2.4	6.5	0.269
4.25	0.75	2.1	10:05	00:45:05	0.061	18.5	29.1	8		0.061	28.81	28.8		26.6	1.2	30.3	1.095
3.25	2.25	0.1	10:04	01:21:02	0.062	21	23.6	13		0.062	23.12	23.1		26.66	2.5	5.85	0.203
1.75	4.25	0.1	11:01	01:57:43	0.06	21.6	23.6	17		0.062	23.1	23.1		26.19	2.5	5.42	0.143
1.75	1.25	0.1	10:03	01:14:48	0.061	21.3	23.6	12		0.063	23.1	23.1		25.47	2.6	5.06	0.052
3.25	4.25	2.1	11:01	01:57:43	0.063	23.9	28.8	17		0.063	28.52	28.5		26.61	1.4	28.5	1.054
0.75	2.75	0.1	9:040	00:20:32	0.062	27.2	22.2	4		0.064	21.73	21.7		25.42	3.2	5.74	-0.19
2.25	3.25	2.6	11:03	02:11:08	0.07	30.2	29.2	19		0.064	28.61	28.6		27.7	1.5	36.2	1.219
3.25	3.75	0.1	11:01	01:50:54	0.066	13.6	23.6	16		0.066	23.12	23.1		28.25	2.9	8.45	0.407
4.25	0.25	0.1	10:01	00:51:25	0.066	29	22.6	9		0.066	22.14	22.1		26.35	3.5	5	-0
4.25	3.25	0.1	9:033	00:13:32	0.066	0	20.5	3		0.066	20.08	20.1		26.95	3.4	6.53	-0.27
4.25	1.25	2.1	9:059	00:39:11	0.066	22.8	28.8	7		0.066	28.52	28.5		26.64	1.6	28.4	1.053
1.75	3.75	0.1	11:01	01:50:54	0.065	20.4	23.7	16		0.066	23.2	23.2		26.31	3.1	5.63	0.175
3.25	3.75	2.6	11:01	01:50:54	0.057	25.4	30.3	16		0.066	29.54	29.5		26.65	1.3	34.6	1.187
0.75	3.25	2.1	9:033	00:13:32	0.066	13.5	28.8	3		0.067	28.43	28.4		26.95	1.5	29.7	1.082
4.25	3.75	0.1	9:027	00:07:16	0.067	6	22.9	2		0.067	22.43	22.4		27.02	3.1	5.36	0.131
1.75	0.75	2.6	10:02	01:07:41	0.073	28.6	29.1	11		0.067	28.51	28.5		26.54	1.7	27.7	1.037
2.25	2.25	2.6	11:03	02:18:20	0.073	32.3	29.3	20		0.067	28.71	28.7		27.23	1.7	33.3	1.16
0.75	1.25	1.7	9:059	00:39:11	0.069	16.5	28.8	7		0.069	28.2	28.2		26.5	1.8	25.6	0.987
4.25	2.75	0.1	9:040	00:20:32	0.07	8.1	20.2	4		0.07	19.79	19.8		26.99	4.3	7.1	-0.32
0.75	1.25	0.1	9:059	00:39:11	0.069	17.5	22.9	7		0.07	22.41	22.4		25.35	3.7	5.13	-0.08
2.25	1.25	0.1	11:04	02:25:20	0.069	20.3	23.7	21		0.07	23.2	23.2		26.95	3.5	6.37	0.257

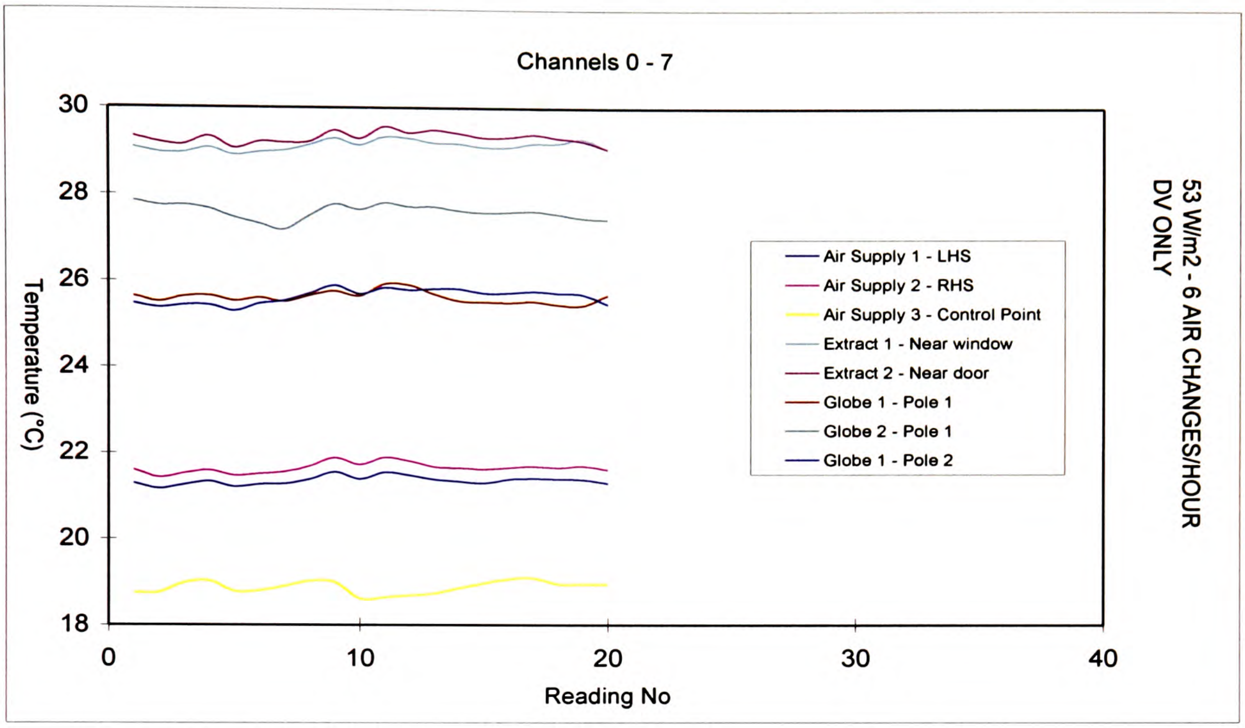
2.25	1.75	2.6	11:03	02:18:20	0.061	37.3	29.6	20		0.071	28.86	28.9		28.1	1.9	40.4	1.303
1.75	0.25	2.6	10:01	00:57:42	0.076	32.1	29	10		0.071	28.42	28.4		26.39	2	26	0.996
1.75	1.75	2.6	10:04	01:21:02	0.076	26.3	29.2	13		0.071	28.61	28.6		26.66	1.9	28.8	1.061
4.25	1.75	0.1	9:052	00:32:30	0.072	11.1	23.2	6		0.072	22.73	22.7		26.48	3.7	5.26	0.113
0.75	4.25	2.6	9:020	00:00:00	0.079	26.5	28.8	1		0.074	28.22	28.2		26.79	2.2	26.9	1.018
49.25	49.25	0.1	11:05	02:31:16	0.073	19	23.6	22		0.074	23.1	23.1		26.63	4	5.82	0.199
2.25	0.75	0.1	11:04	02:25:20	0.076	15.8	24.4	21		0.077	23.91	23.9		26.95	3.9	7.91	0.374
0.75	2.25	0.1	9:046	00:26:21	0.078	24.2	22	5		0.079	21.53	21.5		25.31	5.4	6.17	-0.24
1.75	0.75	0.1	10:02	01:07:41	0.079	10.1	23.7	11		0.08	23.2	23.2		25.43	4.2	5.08	0.064
2.25	3.75	0.1	11:02	02:04:14	0.079	18.4	22.9	18		0.08	22.43	22.4		27.39	4.9	5.66	0.179
2.25	0.25	2.6	11:05	02:31:16	0.071	34	29.3	22		0.081	28.57	28.6		27.32	2.6	32.1	1.135
2.25	3.75	2.6	11:02	02:04:14	0.071	33.4	29.4	18		0.081	28.67	28.7		26.87	2.5	29.9	1.087
3.25	0.25	2.6	10:01	00:57:42	0.071	33.6	29.4	10		0.081	28.67	28.7		28.05	2.5	37.7	1.25
3.25	2.25	2.6	10:04	01:21:02	0.071	28.9	30	13		0.081	29.25	29.3		27.08	2.2	35.3	1.201
0.75	3.75	2.6	9:027	00:07:16	0.087	31.4	29	2		0.083	28.42	28.4		27.02	2.8	28.8	1.061
3.25	1.75	2.6	10:03	01:14:48	0.074	35.1	29.7	12		0.084	28.96	29		27.37	2.6	35	1.194
4.25	4.25	0.1	9:020	00:00:00	0.083	0	20.8	1		0.085	20.37	20.4		26.79	5.3	6.19	-0.24
3.25	4.25	2.6	11:01	01:57:43	0.075	21.8	29.1	17		0.085	28.38	28.4		26.61	2.7	26.2	1.002
0.75	0.75	0.1	10:05	00:45:05	0.084	6.7	22.4	8		0.085	21.92	21.9		25.36	5.1	5.55	-0.16
3.25	3.25	0.1	10:05	01:33:21	0.084	11.7	22	15		0.086	21.55	21.6		27.44	5.5	5.05	0.049
2.25	0.75	2.6	11:04	02:25:20	0.079	29.1	29.8	21		0.089	29.06	29.1		27.79	2.7	38.1	1.258
1.75	2.25	2.6	10:04	01:27:01	0.095	28.6	29.2	14		0.092	28.61	28.6		26.94	3.1	28.9	1.065
1.75	2.75	2.6	10:05	01:33:21	0.096	30.7	29.2	15		0.093	28.61	28.6		27.44	3.2	32	1.131
2.25	0.25	0.1	11:05	02:31:16	0.091	10.8	23.2	22		0.093	22.73	22.7		27.92	5.7	6.83	0.297
3.25	2.75	0.1	10:04	01:27:01	0.092	12.3	21.7	14		0.094	21.26	21.3		26.94	6.6	5.09	-0.07
0.75	1.75	0.1	9:052	00:32:30	0.098	15.3	21.5	6		0.098	21.04	21		25.42	7.4	6.97	-0.31
3.25	4.25	0.1	11:01	01:57:43	0.098	10	22.2	17		0.101	21.75	21.7		27.99	6.8	5.38	0.136
4.25	0.75	0.1	10:05	00:45:05	0.1	8	22.4	8		0.103	21.94	21.9		26.3	6.8	5.04	-0.05
0.75	0.25	0.1	10:01	00:51:25	0.111	14.5	21.7	9		0.111	21.24	21.2		25.42	8.4	6.72	-0.29
1.75	4.25	2.6	11:01	01:57:43	0.113	26.1	29.1	17		0.112	28.51	28.5		27.99	4.1	33.4	1.161
2.25	4.25	2.6	11:02	02:04:14	0.118	18.7	29.1	18		0.117	28.51	28.5		27.39	4.1	29.3	1.073
3.25	0.75	2.6	10:02	01:07:41	0.122	20.8	29.2	11		0.132	28.47	28.5		27.73	4.9	30.4	1.098
1.75	3.75	2.6	11:01	01:50:54	0.142	17.8	29.2	16		0.144	28.61	28.6		28.25	5.1	33.7	1.168
4.25	2.25	0.1	9:046	00:26:21	0.192	14.5	19.9	5		0.204	19.49	19.5		26.55	19	17.8	-0.78

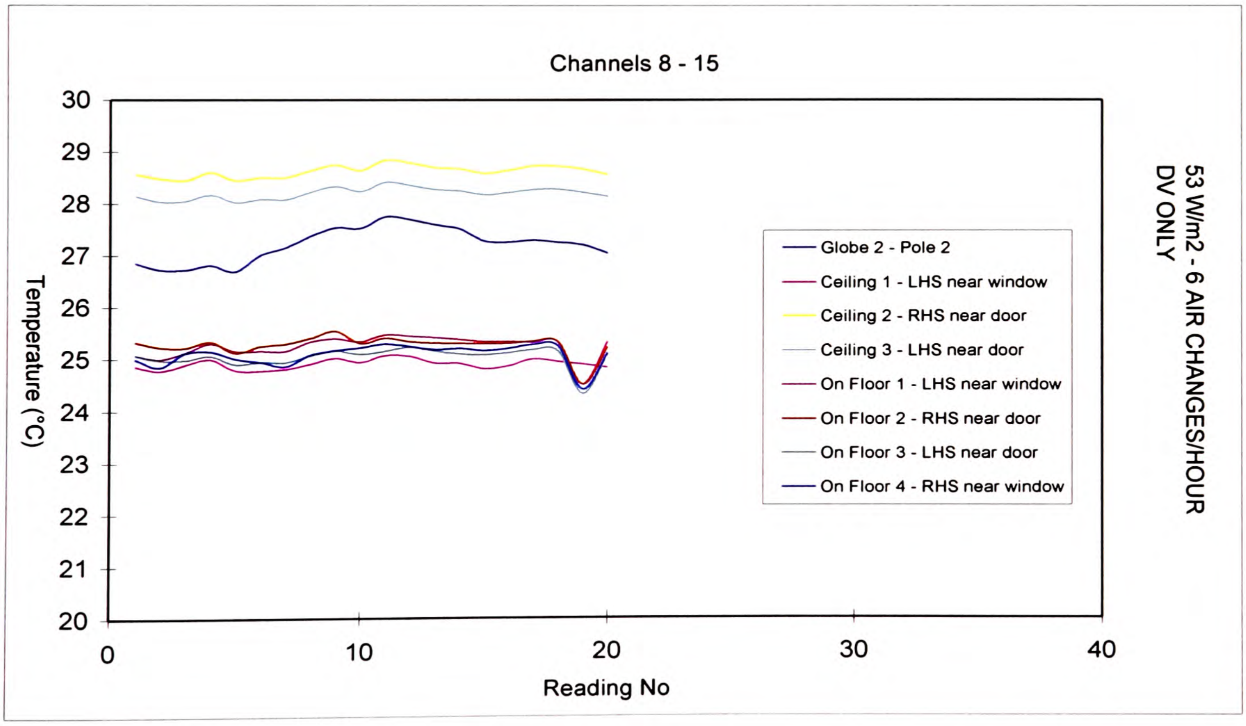
Room Temperature Data (Surface Thermocouples)

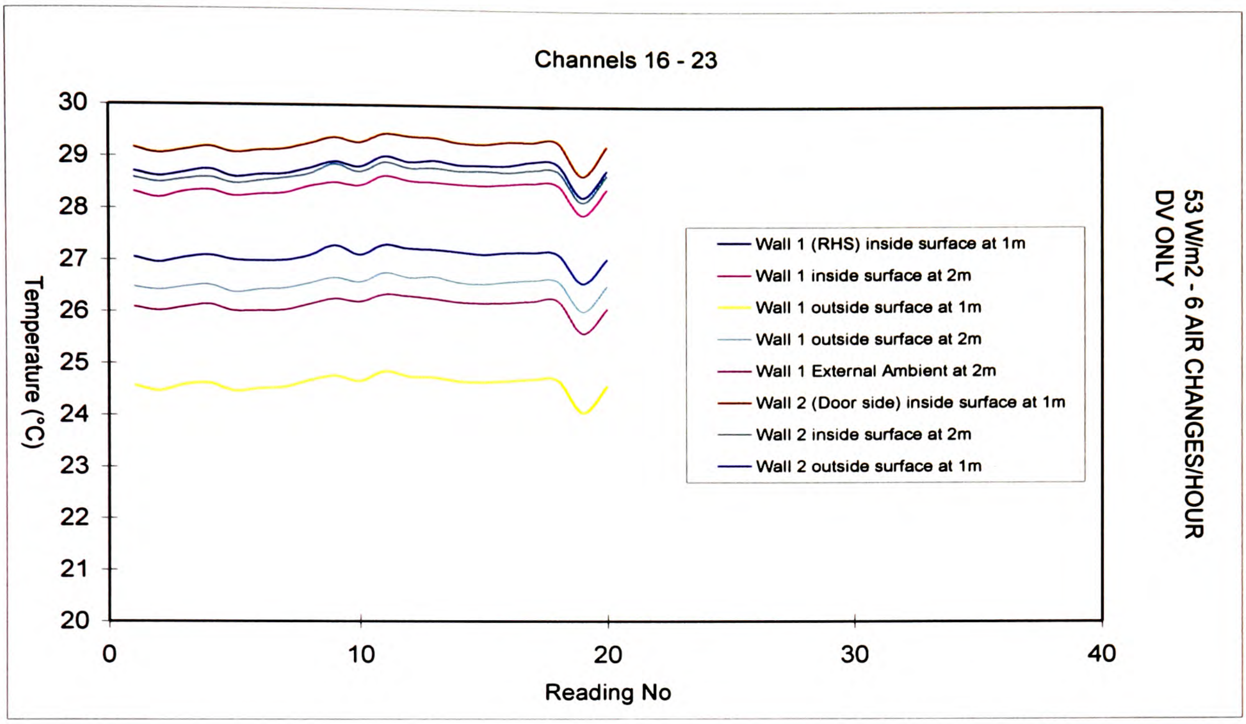
Experiment 2 - 53 W/m^2 with 6 air changes per hour

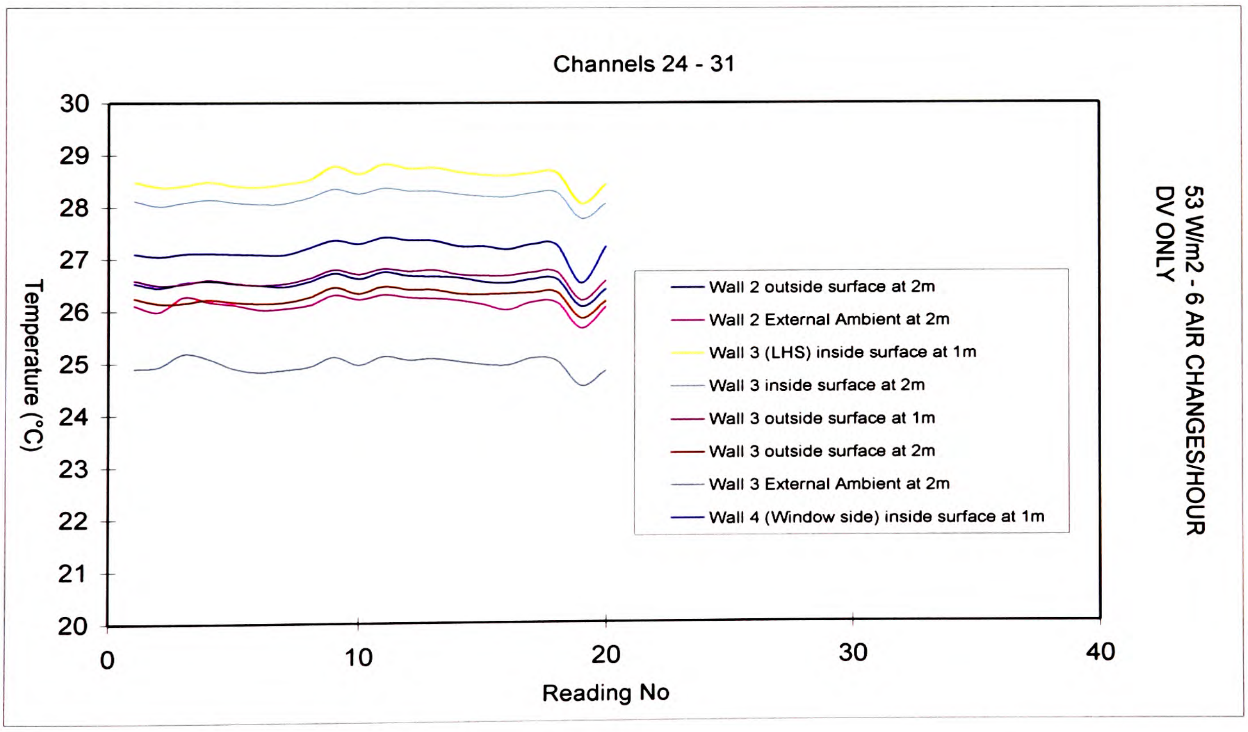
Real time heat loss calculations highlighted in green

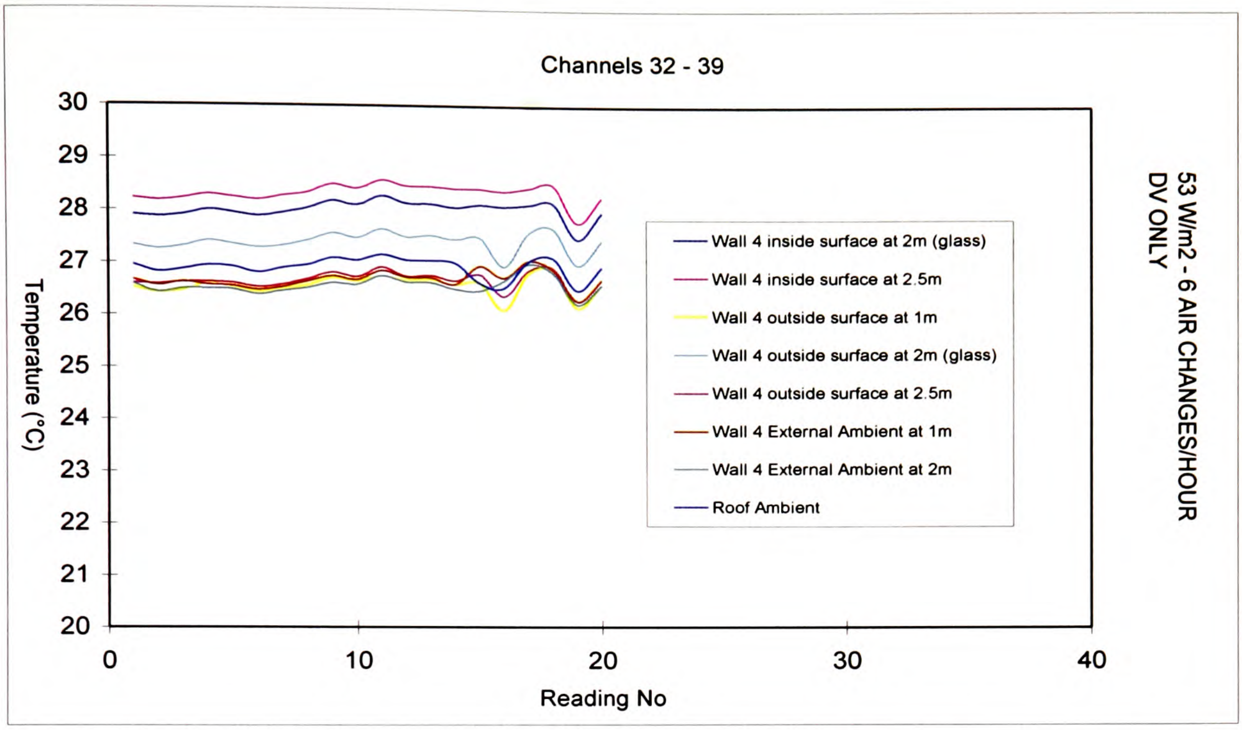
Channel	Location	Temp (°C)	A Positive figure indicates flux into the facility				
CH0	Air Supply 1 - LHS	21.31			3		
Ch1	Air Supply 2 - RHS	21.63					
CH2	Air Supply Andrew Geens	18.95	Fluxes	Area	Δ T	U-value	Flux
CH3	Extract 1 - Near w indow	29.06		(m²)	(°C)	(W/m2K)	(W)
CH4	Extract 2 - Near door	29.07					
CH5	Globe 1 - Pole 1	25.69	Floor 1	5.0625	-3.62	0.715	-13.103693
CH6	Globe 2 - Pole 1	27.43	Floor 2	5.0625	-3.74	0.715	-13.552619
CH7	Globe 1 - Pole 2	25.47	Floor 3	5.0625	-3.55	0.715	-12.845649
CH8	Globe 2 - Pole 2	27.03	Floor 4	5.0625	-3.38	0.715	-12.241189
CH9	Ceiling 1 - LHS near w indow	24.84	Roof	20.25	-2.00	1.21	-48.981072
CH10	Ceiling 2 - RHS near door	28.55	Wall 1 @ 2.9m	1.8	-4.16	0.717	-5.3741391
CH11	Ceiling 3 - LHS near door	28.13	Wall 1 @ 2m	12.85	-1.87	0.717	-17.257224
CH12	On Floor 1 - LHS near w indow	25.33	Wall 1 average	13.95	-2.17	0.717	-21.713456
CH13	On Floor 2 - RHS near door	25.23	Wall 2 @ 2.9m	1.8	-2.17	0.717	-2.8068029
CH14	On Floor 3 - LHS near door	25.09	Wall 2 @ 2m	12.85	-2.27	0.717	-20.91921
CH15	On Floor 4 - RHS near w indow	25.10	Wall 2 average	13.95	-2.26	0.717	-22.585519
CH16 - Ch0	Wall 1 (RHS) inside surface at 2.9m	28.76	Wall 3 @ 2.9	1.8	-1.86	0.717	-2.394668
CH17 - Ch1	Wall 1 inside surface at 2m	28.41	Wall 3 @ 2m	12.85	-1.88	0.717	-17.275219
CH18 - Ch2	Wall 1 outside surface at 2.9m	24.60	Wall 3 average	13.95	-1.87	0.717	-18.728635
CH19 - Ch3	Wall 1 outside surface at 2m	26.54	Wall 4 @ 1m	4.05	1.04	0.402	1.6916977
CH20 - Ch4	Wall 1 External Ambient at 2m	26.10	Wall 4 @ 2m	5.148	-0.54	8.54	-23.828101
CH21 - Ch5	Wall 2 (Door side) inside surface at 2.9m	29.24	Wall 4 @ 2.5 m	4.752	-1.57	0.402	-2.9960432
CH22 - Ch6	Wall 2 inside surface at 2m	28.67	Wall 4 average	13.95	-0.43	3.66	-22.087428
CH23 - Ch7	Wall 2 outside surface at 2.9m	27.06	Beam 1		1.73	0	0
CH24 - Ch8	Wall 2 outside surface at 2m	26.40	Beam 2		2.16	0	0
CH25 - Ch9	Wall 2 External Ambient at 2m	26.07	Beam 3		10.01	0	0
CH26 - Ch10	Wall 3 (LHS) inside surface at 2.9m	28.43	Air		9.52		
CH27 - Ch11	Wall 3 inside surface at 2m	28.06					
CH28 - Ch12	Wall 3 outside surface at 2.9m	26.57					
CH29 - Ch13	Wall 3 outside surface at 2m	26.18					
CH30 - Ch14	Wall 3 External Ambient at 2m	24.84					
CH31 - Ch15	Wall 4 (Window side) inside surface at 1m	27.23					
CH32 - Ch0	Wall 4 inside surface at 2m (glass)	27.97					
CH33 - Ch1	Wall 4 inside surface at 2.5m	28.27					
CH34 - Ch2	Wall 4 outside surface at 1m	26.59					
CH35 - Ch3	Wall 4 outside surface at 2m (glass)	27.43					
CH36 - Ch4	Wall 4 outside surface at 2.5m	26.70					
CH37 - Ch5	Wall 4 External Ambient at 1m	26.70		Heat load			1150
CH38 - Ch6	Wall 4 External Ambient at 2m	26.59					
CH39 - Ch7	Roof Ambient 1	26.94		Cooling due to air system			1029.9485
CH40 - Ch8	Under Floor 1 - LHS near w indow	21.71					
CH41 - Ch9	Under Floor 2 - RHS near door	21.48		Cooling due to w ater system			0
CH42 - Ch10	Under Floor 3 - LHS near door	21.54					
CH43 - Ch11	Under Floor 4 - RHS near w indow	21.72		Overall heat flux from facility			-185.83926
CH44 - Ch12	Ceiling 4 - RHS near w indow	28.15					
CH45 - Ch13	Under Roof 1 - Near w indow	28.69		Energy Balance			-65.787747
CH46 - Ch14	Under Roof 2 - Near door	29.23					
CH47 - Ch15	Roof Ambient 2	26.99					
CH48 - Ch0	Column 1 at 0.01 m	24.00		Av Column temps (°C)			
CH49 - Ch1	Column 1 at 0.1 m	24.38		24.095703	0.01		
CH50 - Ch2	Column 1 at 0.6 m	25.25		24.055664	0.1		
CH51 - Ch3	Column 1 at 1.1 m	27.45		25.005371	0.6		
CH52 - Ch4	Column 1 at 1.7 m	28.56		27.125977	1.1		
CH53 - Ch5	Column 1 at 2.1 m	28.77		28.388672	1.7		
CH54 - Ch6	Column 1 at 2.6 m	28.86		28.578613	2.1		
CH55 - Ch7	Column 1 at 2.69 m	28.84		28.758301	2.6		
CH56 - Ch8	Column 2 at 0.01 m	24.19		28.755371	2.69		
CH57 - Ch9	Column 2 at 0.1 m	23.74					
CH58 - Ch10	Column 2 at 0.6 m	24.76					
CH59 - Ch11	Column 2 at 1.1 m	26.80		Air flow rate	0.09	m³/s	
CH60 - Ch12	Column 2 at 1.7 m	28.21		Water flow r	0.00E+00	m³/s	
CH61 - Ch13	Column 2 at 2.1 m	28.39		Air Cp	1010	J/kgK	
CH62 - Ch14	Column 2 at 2.6 m	28.66		Water Cp	4180	J/kgK	
CH63 - Ch15	Column 2 at 2.69 m	28.67		Air density	1.19	kg/m³	
CH64 - Ch0 (PRT)	Beam 1 Supply	27.89		Water Densi	1000	kg/m³	
CH65 - Ch1 (PRT)	Beam 2 Supply	27.75					
CH66 - Ch2 (PRT)	Beam 3 Supply	19.54					
CH67 - Ch3 (PRT)	Beam 1 Return	29.62					
CH68 - Ch4 (PRT)	Beam 2 Return	29.91					
CH69 - Ch5 (PRT)	Beam 3 Return	29.55					


Channels 0 - 7
Temperature (°C)
Reading No
Air Supply 1 - LHS
Air Supply 2 - RHS
Air Supply 3 - Control Point
Extract 1 - Near window
Extract 2 - Near door
Globe 1 - Pole 1
Globe 2 - Pole 1
Globe 1 - Pole 2
53 W/m2 - 6 AIR CHANGES/HOUR
DV ONLY

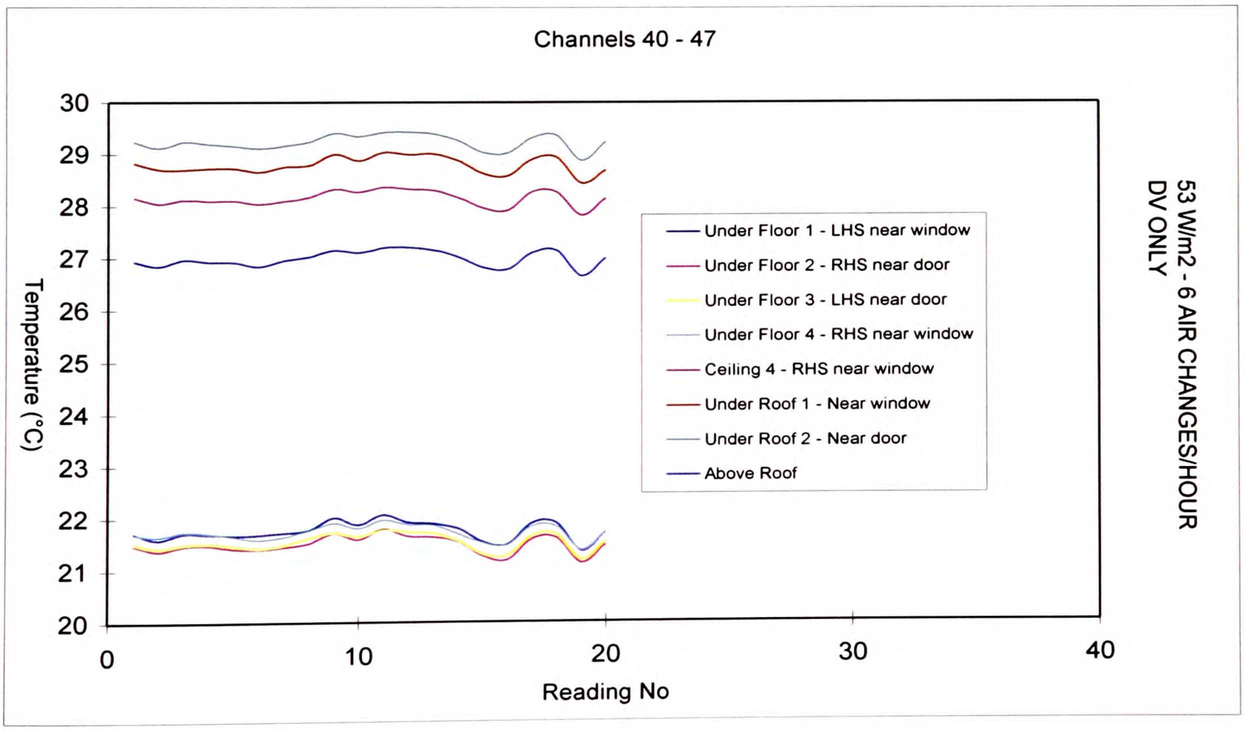

Channels 8 - 15
Temperature (°C)
Reading No
Globe 2 - Pole 2
Ceiling 1 - LHS near window
Ceiling 2 - RHS near door
Ceiling 3 - LHS near door
On Floor 1 - LHS near window
On Floor 2 - RHS near door
On Floor 3 - LHS near door
On Floor 4 - RHS near window
53 W/m2 - 6 AIR CHANGES/HOUR
DV ONLY


Channels 16 - 23
30
29
28
27
26
25
24
23
22
21
20
Temperature (°C)
0
10
20
30
40
Reading No
Wall 1 (RHS) inside surface at 1m
Wall 1 inside surface at 2m
Wall 1 outside surface at 1m
Wall 1 outside surface at 2m
Wall 1 External Ambient at 2m
Wall 2 (Door side) inside surface at 1m
Wall 2 inside surface at 2m
Wall 2 outside surface at 1m
53 W/m2 - 6 AIR CHANGES/HOUR
DV ONLY

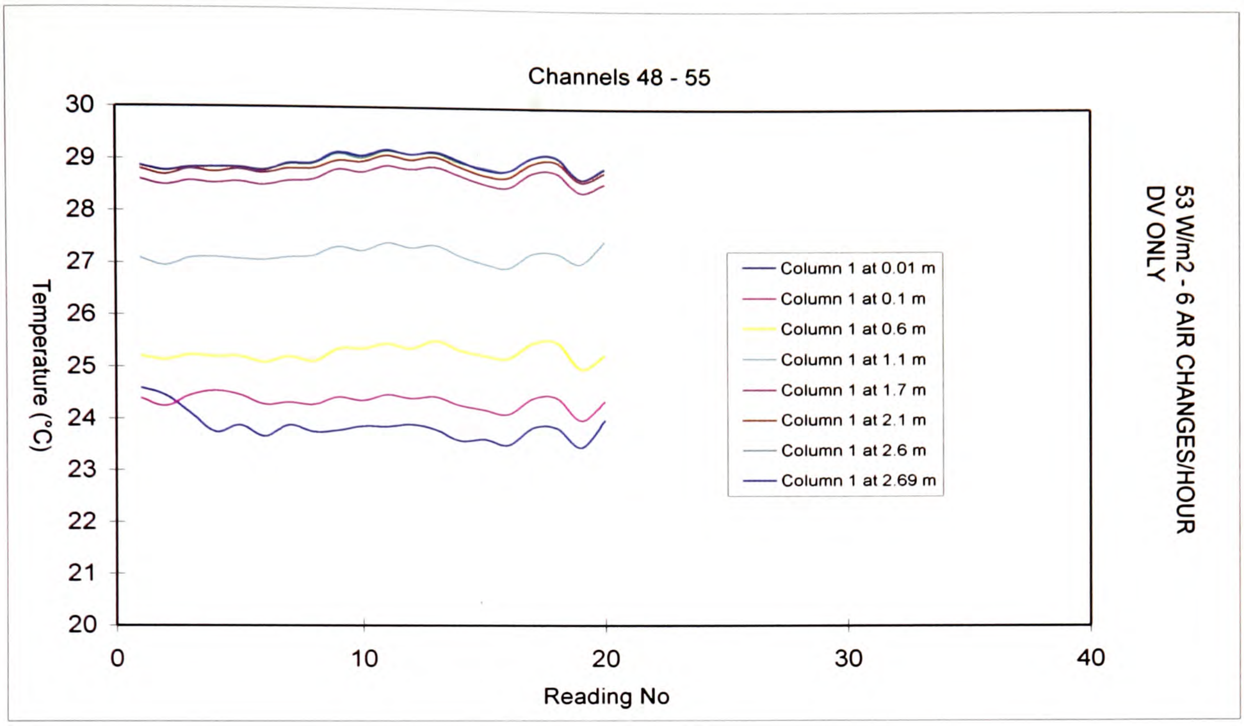

Channels 24 - 31
30
29
28
27
26
25
24
23
22
21
20
Temperature (°C)
0
10
20
30
40
Reading No
Wall 2 outside surface at 2m
Wall 2 External Ambient at 2m
Wall 3 (LHS) inside surface at 1m
Wall 3 inside surface at 2m
Wall 3 outside surface at 1m
Wall 3 outside surface at 2m
Wall 3 External Ambient at 2m
Wall 4 (Window side) inside surface at 1m
53 W/m2 - 6 AIR CHANGES/HOUR
DV ONLY

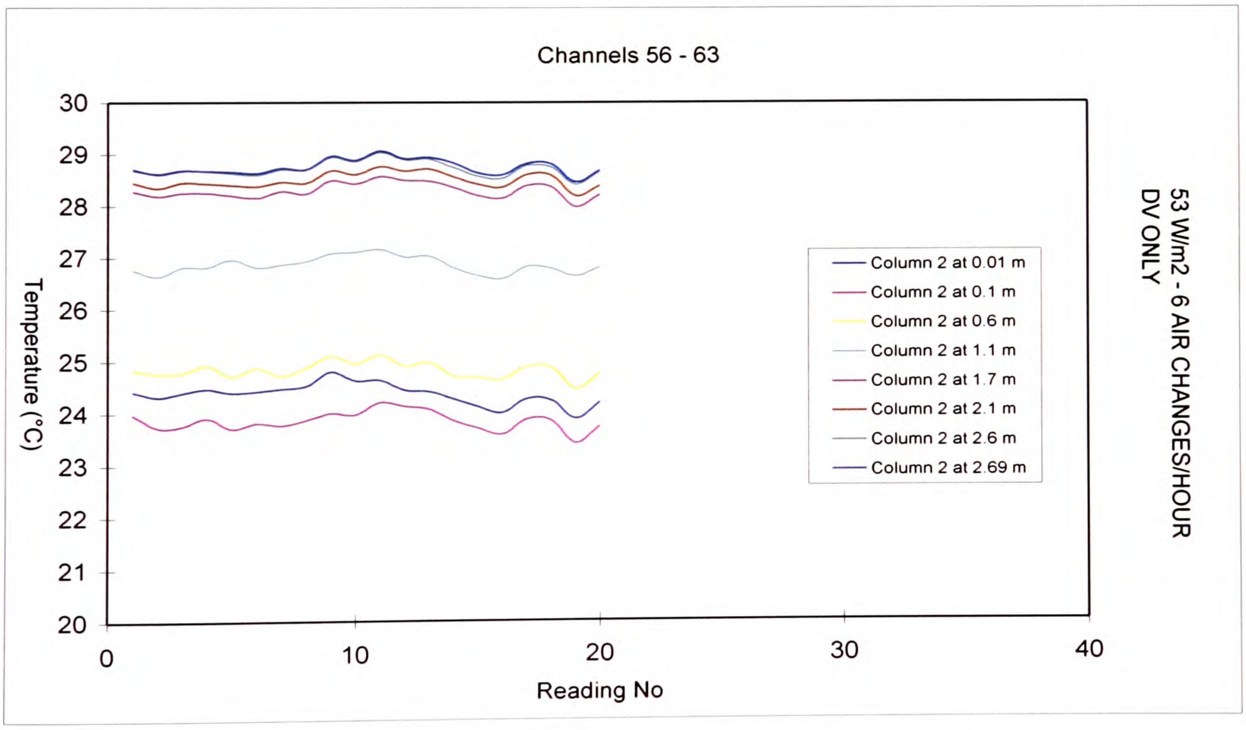


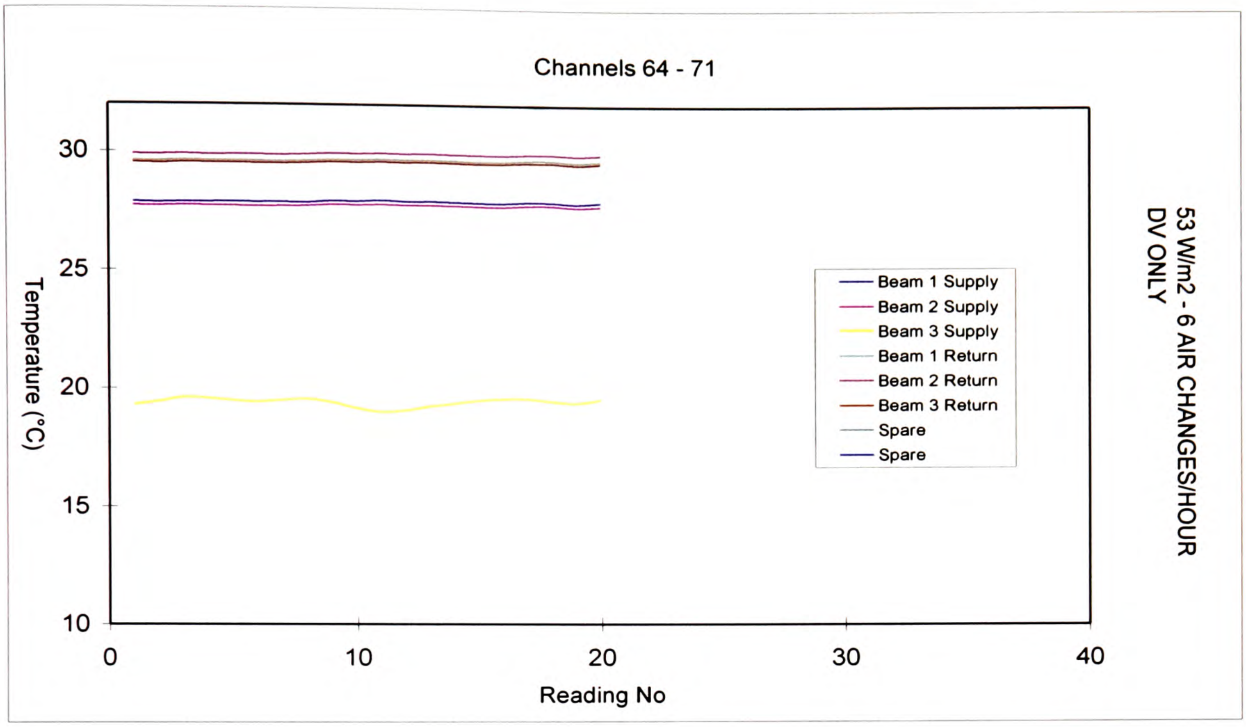
Channels 32 - 39
30
29
28
27
26
25
24
23
22
21
20
Temperature (°C)
0
10
20
30
40
Reading No
Wall 4 inside surface at 2m (glass)
Wall 4 inside surface at 2.5m
Wall 4 outside surface at 1m
Wall 4 outside surface at 2m (glass)
Wall 4 outside surface at 2.5m
Wall 4 External Ambient at 1m
Wall 4 External Ambient at 2m
Roof Ambient
53 W/m2 - 6 AIR CHANGES/HOUR
DV ONLY



Channels 40 - 47
30
29
28
27
26
25
24
23
22
21
20
Temperature (°C)
0
10
20
30
40
Reading No
Under Floor 1 - LHS near window
Under Floor 2 - RHS near door
Under Floor 3 - LHS near door
Under Floor 4 - RHS near window
Ceiling 4 - RHS near window
Under Roof 1 - Near window
Under Roof 2 - Near door
Above Roof
53 W/m2 - 6 AIR CHANGES/HOUR
DV ONLY


Channels 48 - 55
Temperature (°C)
Reading No
30
29
28
27
26
25
24
23
22
21
20
0
10
20
30
40
Column 1 at 0.01 m
Column 1 at 0.1 m
Column 1 at 0.6 m
Column 1 at 1.1 m
Column 1 at 1.7 m
Column 1 at 2.1 m
Column 1 at 2.6 m
Column 1 at 2.69 m
53 W/m2 - 6 AIR CHANGES/HOUR
DV ONLY


Channels 56 - 63
Temperature (°C)
Reading No
30
29
28
27
26
25
24
23
22
21
20
0
10
20
30
40
Column 2 at 0.01 m
Column 2 at 0.1 m
Column 2 at 0.6 m
Column 2 at 1.1 m
Column 2 at 1.7 m
Column 2 at 2.1 m
Column 2 at 2.6 m
Column 2 at 2.69 m
53 W/m2 - 6 AIR CHANGES/HOUR
DV ONLY


Channels 64 - 71
30
25
20
15
10
0
10
20
30
40
Temperature (°C)
Reading No
Beam 1 Supply
Beam 2 Supply
Beam 3 Supply
Beam 1 Return
Beam 2 Return
Beam 3 Return
Spare
Spare
53 W/m2 - 6 AIR CHANGES/HOUR
DV ONLY

Summary sheet for Room Thermal Comfort Data

Experiment 1 - 53 W/m^2 with 9 air changes per hour

Height	Av.Vel	Max.Vel	Min.Vel	Av.Temp	Max.Tem	Min.Temp	Av.PPD	Max.PPD	Min.PPD	Av.PMV	Max.PMV	Min.PMV	
0.1	0.077	0.13026	0.052912	20.5	21.9	19.3	13.63	22.76	7.46	-0.62	-0.344	-0.917	
0.6	0.047	0.08492	0.03595	22	22.4	21.4	7.8	10	6.77	-0.36	-0.292	-0.489	
1.1	0.034	0.03893	0.019781	23.4	23.7	23.2	5.09	5.33	5	-0.01	0.127	-0.126	
1.7	0.042	0.04507	0.033463	25.7	25.8	25.5	7.64	9.44	6.08	0.35	0.461	0.228	
2.1	0.048	0.06665	0.036659	25.9	26.2	25.5	8.15	9.75	6.58	0.38	0.477	0.276	
2.6	0.046	0.13641	0.025962	26	26.4	25.2	8.32	10.16	6.13	0.4	0.497	0.233	
0.1	0.083	0.19754	0.043962	20.2	21.7	18.3	12.91	36.73	6.55	-0.57	-0.273	-1.23	
0.6	0.044	0.07866	0.022546	21.7	22.2	20.9	8.3	9.46	6.5	-0.39	-0.269	-0.462	
1.1	0.042	0.05644	0.031153	23.5	23.8	22.4	5.13	5.41	5	-0.03	0.14	-0.118	
1.7	0.037	0.04289	0.019018	25.5	25.7	25.3	7.05	11.64	5.83	0.3	0.563	0.2	
2.1	0.045	0.05661	0.032364	25.9	26.1	25.4	7.76	13.68	5.98	0.35	0.643	0.217	
2.6	0.056	0.09892	0.037084	26	26.3	25.2	7.94	13.68	5.71	0.37	0.643	0.165	
Occ.Zone	0.0545	0.19754	0.019781	21.88333	23.8	18.3	8.81	36.73	5	-0.33	36.73	-1.23	
				AV TEMP			AV VEL			AV PPD			AV PMV
ADPI =	36.92308	20.5	20.2	20.35	0.077	0.083	0.08	13.63	12.91	13.27	-0.62	-0.57	-0.595
		22	21.7	21.85	0.047	0.044	0.0455	7.8	8.3	8.05	-0.36	-0.39	-0.375
Clo value:	0.6	23.4	23.5	23.45	0.034	0.042	0.038	5.09	5.13	5.11	-0.01	-0.03	-0.02
Ext.Work:	0	25.7	25.5	25.6	0.042	0.037	0.0395	7.64	7.05	7.345	0.35	0.3	0.325
Humidity:	50	25.9	25.9	25.9	0.048	0.045	0.0465	8.15	7.76	7.955	0.38	0.35	0.365
Met.Rate:	1.2	26	26	26	0.046	0.056	0.051	8.32	7.94	8.13	0.4	0.37	0.385

Detailed Thermal Comfort Data

Experiment 1 - 53 W/m^2 with 9 air changes per hour

			Test Start Date		9\8\1996												
			Measurement Time: 180 secs.														
X-Pos (m)	Y-Pos (m)	Height (m)	Time	Rel.Time	Vel	Turb'ce	Temp	Read'g	Globe temp	Corr'd Vel	Corr'd Temp	Shifted Temp	Shifted Globe temp	Rad Temp	DR	PPD	PMV
0.75	0.25	0.1	17:0	00:48:05	0.05	28.2	20.5	9		0.055	20.1	20.1		23.4	1.89	16	-0.7
1.75	0.25	0.1	17:0	00:53:42	0.07	18.1	21.7	10		0.071	21.2	21.2		23.4	4.26	11	-0.5
2.75	0.25	0.1	17:0	01:32:05	0.07	19.6	21.2	39		0.066	20.7	20.7		24	3.77	11	-0.5
3.75	0.25	0.1	16:0	00:00:00	0.06	20.9	20.5	23		0.063	20.1	20.1		23.8	3.34	14	-0.7
0.75	0.75	0.1	17:0	00:42:17	0.09	4.4	20.6	8		0.091	20.2	20.2		23.5	6.23	15	-0.7
1.75	0.75	0.1	17:0	00:59:44	0.08	15.6	21.2	11		0.078	20.7	20.7		23.5	5.21	12	-0.6
2.75	0.75	0.1	17:0	01:26:45	0.05	39.6	21.9	38		0.053	21.4	21.4		24.6	1.32	7.5	-0.3
3.75	0.75	0.1	16:0	00:06:25	0.1	10.9	19.8	24		0.104	19.4	19.4		23.5	8.52	19	-0.8
0.75	1.25	0.1	16:0	00:36:03	0.09	8.8	19.9	7		0.092	19.5	19.5		23.8	6.94	17	-0.8
1.75	1.25	0.1	17:0	01:04:45	0.06	21	22.1	12		0.059	21.6	21.6		23.9	2.36	8.4	-0.4
2.25	1.25	0.1	18:0	01:55:30	0.09	13	20.8	21		0.088	20.4	20.4		23.6	6.35	14	-0.6
3.75	1.25	0.1	16:0	00:12:06	0.09	8.8	20.1	25		0.092	19.7	19.7		23.5	6.85	17	-0.8
0.75	1.75	0.1	16:0	00:30:18	0.13	8.7	19.7	6		0.13	19.3	19.3		23.5	11	23	-0.9
1.75	1.75	0.1	17:0	01:10:08	0.05	20.6	22.4	13		0.055	21.9	21.9		23.3	1.58	8.6	-0.4
2.75	1.75	0.1	17:0	01:20:48	0.07	26.5	21.3	37		0.072	20.8	20.8		23.6	4.8	12	-0.6
3.75	1.75	0.1	16:0	00:18:38	0.08	22.8	20.2	26		0.081	19.8	19.8		23.5	6.29	17	-0.7
0.75	2.25	0.1	16:0	00:24:15	0.1	16.2	19.9	5		0.099	19.5	19.5		23.6	8.38	18	-0.8
1.75	2.25	0.1	17:0	01:15:37	0.05	24.3	21.7	14		0.055	21.2	21.2		23.6	1.71	10	-0.5
2.25	2.25	0.1	18:0	01:49:16	0.08	17.6	21.6	20		0.08	21.1	21.1		23.7	5.37	10	-0.5
2.75	2.25	0.1	17:0	01:15:37	0.05	24.3	21.7	36		0.055	21.2	21.2		23.6	1.71	10	-0.5
3.75	2.25	0.1	16:0	00:24:15	0.1	16.2	19.9	27		0.099	19.5	19.5		23.6	8.38	18	-0.8
0.75	2.75	0.1	16:0	00:18:38	0.08	22.8	20.2	4		0.081	19.8	19.8		23.5	6.29	17	-0.7
1.75	2.75	0.1	17:0	01:20:48	0.07	26.5	21.3	15		0.072	20.8	20.8		23.6	4.8	12	-0.6
2.75	2.75	0.1	17:0	01:10:08	0.05	20.6	22.4	35		0.055	21.9	21.9		23.3	1.58	8.6	-0.4
3.75	2.75	0.1	16:0	00:30:18	0.13	8.7	19.7	28		0.13	19.3	19.3		23.5	11	23	-0.9
0.75	3.25	0.1	16:0	00:12:06	0.09	8.8	20.1	3		0.092	19.7	19.7		23.5	6.85	17	-0.8
2.25	3.25	0.1	18:0	01:43:37	0.06	27.6	22	19		0.057	21.5	21.5		23.9	2.1	8.6	-0.4
2.75	3.25	0.1	17:0	01:04:45	0.06	21	22.1	34		0.059	21.6	21.6		23.9	2.36	8.4	-0.4
3.75	3.25	0.1	16:0	00:36:03	0.09	8.8	19.9	29		0.092	19.5	19.5		23.8	6.94	17	-0.8
0.75	3.75	0.1	16:0	00:06:25	0.1	10.9	19.8	2		0.104	19.4	19.4		23.5	8.52	19	-0.8
1.75	3.75	0.1	17:0	01:26:45	0.05	39.6	21.9	16		0.053	21.4	21.4		24.6	1.32	7.5	-0.3
2.75	3.75	0.1	17:0	00:59:44	0.08	15.6	21.2	33		0.078	20.7	20.7		23.5	5.21	12	-0.6
3.75	3.75	0.1	17:0	00:42:17	0.09	4.4	20.6	30		0.091	20.2	20.2		23.5	6.23	15	-0.7
0.75	4.25	0.1	16:0	00:00:00	0.06	20.9	20.5	1		0.063	20.1	20.1		23.8	3.34	14	-0.7
1.75	4.25	0.1	17:0	01:32:05	0.07	19.6	21.2	17		0.066	20.7	20.7		24	3.77	11	-0.5

2.25	4.25	0.1	17:0	01:37:47	0.1	21.2	20.8	18		0.079	20.4	20.4		23.7	5.7	13	-0.6
2.75	4.25	0.1	17:0	00:53:42	0.1	18.1	21.7	32		0.071	21.2	21.2		23.4	4.26	11	-0.5
3.75	4.25	0.1	17:0	00:48:05	0.1	28.2	20.5	31		0.055	20.1	20.1		23.4	1.89	16	-0.7
0.25	4.25	0.1	18:0	02:00:36	0.1	23.8	21.3	22		0.068	20.8	20.8		23.3	4.15	13	-0.6
0.75	0.25	0.6	17:0	00:48:05	0	21	21.8	9	22.6	0.041	21.4	21.4	22.63	23.4	0	10	-0.5
1.75	0.25	0.6	17:0	00:53:42	0	19.1	22.1	10	22.7	0.04	21.7	21.7	22.74	23.4	0	9.1	-0.4
2.75	0.25	0.6	17:0	01:32:05	0	31.1	22.4	39	23.2	0.051	22	22	23.17	24	0.71	7.1	-0.3
3.75	0.25	0.6	16:0	00:00:00	0	31.4	22.7	23	23.2	0.043	22.3	22.3	23.2	23.8	0	6.8	-0.3
0.75	0.75	0.6	17:0	00:42:17	0	13.5	22.4	8	22.9	0.046	22	22	22.89	23.5	0	8	-0.4
1.75	0.75	0.6	17:0	00:59:44	0	27.4	22.4	11	23	0.036	22	22	22.95	23.5	0	7.9	-0.4
2.75	0.75	0.6	17:0	01:26:45	0.1	19.5	21.9	38	23.1	0.085	21.5	21.5	23.11	24.6	5.86	7.2	-0.3
3.75	0.75	0.6	16:0	00:06:25	0	34.7	22.7	24	23	0.044	22.3	22.3	23.02	23.5	0	7.2	-0.3
0.75	1.25	0.6	16:0	00:36:03	0	16.7	22.4	7	23.1	0.042	22	22	23.09	23.8	0	7.4	-0.3
1.75	1.25	0.6	17:0	01:04:45	0	22.4	21.9	12	22.9	0.051	21.5	21.5	22.87	23.9	0.71	8.7	-0.4
2.25	1.25	0.6	18:0	01:55:30	0	30.6	22	21	22.8	0.052	21.6	21.6	22.75	23.6	1.06	9	-0.4
3.75	1.25	0.6	16:0	00:12:06	0	14.7	22.7	25	23	0.045	22.3	22.3	23.02	23.5	0	7.2	-0.3
0.75	1.75	0.6	16:0	00:30:18	0	15.8	22.4	6	22.9	0.04	22	22	22.89	23.5	0	8.1	-0.4
1.75	1.75	0.6	17:0	01:10:08	0	19.3	22.7	13	22.9	0.047	22.3	22.3	22.91	23.3	0	7.5	-0.3
2.75	1.75	0.6	17:0	01:20:48	0	45	22.4	37	23	0.041	22	22	22.96	23.6	0	7.8	-0.4
3.75	1.75	0.6	16:0	00:18:38	0	10.7	22.8	26	23.1	0.046	22.4	22.4	23.08	23.5	0	7	-0.3
0.75	2.25	0.6	16:0	00:24:15	0	10.5	22.5	5	23	0.047	22.1	22.1	23.01	23.6	0	7.5	-0.3
1.75	2.25	0.6	17:0	01:15:37	0	40.9	22.7	14	23.1	0.038	22.3	22.3	23.1	23.6	0	7.1	-0.3
2.25	2.25	0.6	18:0	01:49:16	0	44.8	22	20	22.8	0.053	21.6	21.6	22.83	23.7	1.44	8.6	-0.4
2.75	2.25	0.6	17:0	01:15:37	0	40.9	22.7	36	23.1	0.038	22.3	22.3	23.1	23.6	0	7.1	-0.3
3.75	2.25	0.6	16:0	00:24:15	0	10.5	22.5	27	23	0.047	22.1	22.1	23.01	23.6	0	7.5	-0.3
0.75	2.75	0.6	16:0	00:18:38	0	10.7	22.8	4	23.1	0.046	22.4	22.4	23.08	23.5	0	7	-0.3
1.75	2.75	0.6	17:0	01:20:48	0	45	22.4	15	23	0.041	22	22	22.96	23.6	0	7.8	-0.4
2.75	2.75	0.6	17:0	01:10:08	0	19.3	22.7	35	22.9	0.047	22.3	22.3	22.91	23.3	0	7.5	-0.3
3.75	2.75	0.6	16:0	00:30:18	0	15.8	22.4	28	22.9	0.04	22	22	22.89	23.5	0	8.1	-0.4
0.75	3.25	0.6	16:0	00:12:06	0	14.7	22.7	3	23	0.045	22.3	22.3	23.02	23.5	0	7.2	-0.3
2.25	3.25	0.6	18:0	01:43:37	0.1	27.6	22.1	19	23	0.055	21.7	21.7	22.95	23.9	1.78	8	-0.4
2.75	3.25	0.6	17:0	01:04:45	0	22.4	21.9	34	22.9	0.051	21.5	21.5	22.87	23.9	0.71	8.7	-0.4
3.75	3.25	0.6	16:0	00:36:03	0	16.7	22.4	29	23.1	0.042	22	22	23.09	23.8	0	7.4	-0.3
0.75	3.75	0.6	16:0	00:06:25	0	34.7	22.7	2	23	0.044	22.3	22.3	23.02	23.5	0	7.2	-0.3
1.75	3.75	0.6	17:0	01:26:45	0.1	19.5	21.9	16	23.1	0.085	21.5	21.5	23.11	24.6	5.86	7.2	-0.3
2.75	3.75	0.6	17:0	00:59:44	0	27.4	22.4	33	23	0.036	22	22	22.95	23.5	0	7.9	-0.4
3.75	3.75	0.6	17:0	00:42:17	0	13.5	22.4	30	22.9	0.046	22	22	22.89	23.5	0	8	-0.4
0.75	4.25	0.6	16:0	00:00:00	0	31.4	22.7	1	23.2	0.043	22.3	22.3	23.2	23.8	0	6.8	-0.3
1.75	4.25	0.6	17:0	01:32:05	0	31.1	22.4	17	23.2	0.051	22	22	23.17	24	0.71	7.1	-0.3
2.25	4.25	0.6	17:0	01:37:47	0	30.1	22.4	18	23	0.044	22	22	23.03	23.7	0	7.6	-0.4
2.75	4.25	0.6	17:0	00:53:42	0	19.1	22.1	32	22.7	0.04	21.7	21.7	22.74	23.4	0	9.1	-0.4
3.75	4.25	0.6	17:0	00:48:05	0	21	21.8	31	22.6	0.041	21.4	21.4	22.63	23.4	0	10	-0.5
49.3	49.3	0.6	18:0	02:00:36	0	29.1	22.5	22	22.8	0.045	22.1	22.1	22.84	23.3	0	8	-0.4
0.75	0.25	1.1	17:0	00:48:05	0	12.3	23.8	9	23.6	0.033	23.4	23.4	23.57	23.7	0	5.3	-0.1
1.75	0.25	1.1	17:0	00:53:42	0	8	23.8	10	23.7	0.034	23.4	23.4	23.73	23.9	0	5.2	-0.1
2.75	0.25	1.1	17:0	01:32:05	0	13.7	23.9	39	24.6	0.036	23.5	23.5	24.59	25.2	0	5.2	0.09
3.75	0.25	1.1	16:0	00:00:00	0	11.5	23.9	23	24.3	0.033	23.5	23.5	24.25	24.7	0	5	0.02
0.75	0.75	1.1	17:0	00:42:17	0	7.8	23.6	8	23.8	0.035	23.2	23.2	23.8	24.2	0	5.2	-0.1
1.75	0.75	1.1	17:0	00:59:44	0	11.1	23.9	11	24	0.034	23.5	23.5	24.03	24.3	0	5	-0
2.75	0.75	1.1	17:0	01:26:45	0	19.9	24.1	38	24.7	0.039	23.7	23.7	24.67	25.3	0	5.3	0.13
3.75	0.75	1.1	16:0	00:06:25	0	10.2	23.9	24	24.2	0.034	23.5	23.5	24.19	24.6	0	5	0.01
0.75	1.25	1.1	16:0	00:36:03	0	7.8	23.9	7	23.9	0.035	23.5	23.5	23.93	24.2	0	5	-0
1.75	1.25	1.1	17:0	01:04:45	0	19.8	23.8	12	24	0.035	23.4	23.4	23.97	24.3	0	5	-0
2.25	1.25	1.1	18:0	01:55:30	0	8.6	23.7	21	24.2	0.037	23.3	23.3	24.2	24.8	0	5	-0
3.75	1.25	1.1	16:0	00:12:06	0	4.5	23.9	25	24.3	0.035	23.5	23.5	24.29	24.8	0	5	0.03
0.75	1.75	1.1	16:0	00:30:18	0	8.5	23.8	6	23.8	0.037	23.4	23.4	23.78	24	0	5.1	-0.1
1.75	1.75	1.1	17:0	01:10:08	0	9.1	23.6	13	24	0.034	23.2	23.2	23.98	24.4	0	5.1	-0.1
2.75	1.75	1.1	17:0	01:20:48	0	17.5	23.8	37	24.5	0.036	23.4	23.4	24.48	25.1	0	5.1	0.06
3.75	1.75	1.1	16:0	00:18:38	0	0	23.9	26	24.3	0.036	23.5	23.5	24.25	24.7	0	5	0.02
0.75	2.25	1.1	16:0	00:24:15	0	6.2	23.8	5	24	0.035	23.4	23.4	24.04	24.4	0	5	-0
1.75	2.25	1.1	17:0	01:15:37	0	6.2	23.7	14	24.1	0.036	23.3	23.3	24.13	24.6	0	5	-0
2.25	2.25	1.1	18:0	01:49:16	0	9.1	23.8	20	24.2	0.034	23.4	23.4	24.21	24.7	0	5	0
2.75	2.25	1.1	17:0	01:15:37	0	6.2	23.7	36	24.1	0.036	23.3	23.3	24.13	24.6	0	5	-0
3.75	2.25	1.1	16:0	00:24:15	0	6.2	23.8	27	24	0.035	23.4	23.4	24.04	24.4	0	5	-0
0.75	2.75	1.1	16:0	00:18:38	0	0	23.9	4	24.3	0.036	23.5	23.5	24.25	24.7	0	5	0.02

1.75	2.75	1.1	17:0	01:20:48	0	17.5	23.8	15	24.5	0.036	23.4	23.4	24.48	25.1	0	5.1	0.06
2.75	2.75	1.1	17:0	01:10:08	0	9.1	23.6	35	24	0.034	23.2	23.2	23.98	24.4	0	5.1	-0.1
3.75	2.75	1.1	16:0	00:30:18	0	8.5	23.8	28	23.8	0.037	23.4	23.4	23.78	24	0	5.1	-0.1
0.75	3.25	1.1	16:0	00:12:06	0	4.5	23.9	3	24.3	0.035	23.5	23.5	24.29	24.8	0	5	0.03
2.25	3.25	1.1	18:0	01:43:37	0	11	23.8	19	24.4	0.035	23.4	23.4	24.42	25	0	5	0.05
2.75	3.25	1.1	17:0	01:04:45	0	19.8	23.8	34	24	0.035	23.4	23.4	23.97	24.3	0	5	-0
3.75	3.25	1.1	16:0	00:36:03	0	7.8	23.9	29	23.9	0.035	23.5	23.5	23.93	24.2	0	5	-0
0.75	3.75	1.1	16:0	00:06:25	0	10.2	23.9	2	24.2	0.034	23.5	23.5	24.19	24.6	0	5	0.01
1.75	3.75	1.1	17:0	01:26:45	0	19.9	24.1	16	24.7	0.039	23.7	23.7	24.67	25.3	0	5.3	0.13
2.75	3.75	1.1	17:0	00:59:44	0	11.1	23.9	33	24	0.034	23.5	23.5	24.03	24.3	0	5	-0
3.75	3.75	1.1	17:0	00:42:17	0	7.8	23.6	30	23.8	0.035	23.2	23.2	23.8	24.2	0	5.2	-0.1
0.75	4.25	1.1	16:0	00:00:00	0	11.5	23.9	1	24.3	0.033	23.5	23.5	24.25	24.7	0	5	0.02
1.75	4.25	1.1	17:0	01:32:05	0	13.7	23.9	17	24.6	0.036	23.5	23.5	24.59	25.2	0	5.2	0.09
2.25	4.25	1.1	17:0	01:37:47	0	8	23.8	18	24.4	0.033	23.4	23.4	24.44	25	0	5	0.05
2.75	4.25	1.1	17:0	00:53:42	0	8	23.8	32	23.7	0.034	23.4	23.4	23.73	23.9	0	5.2	-0.1
3.75	4.25	1.1	17:0	00:48:05	0	12.3	23.8	31	23.6	0.033	23.4	23.4	23.57	23.7	0	5.3	-0.1
49.3	49.3	1.1	18:0	02:00:36	0	48.9	24	22	24.3	0.02	23.6	23.6	24.28	24.6	0	5	0.02
0.75	0.25	1.7	17:0	00:48:05	0	15.2	26.1	9		0.04	25.6	25.6		23.7	0	6.1	0.23
1.75	0.25	1.7	17:0	00:53:42	0	8.4	26.2	10		0.042	25.7	25.7		23.9	0	6.6	0.28
2.75	0.25	1.7	17:0	01:32:05	0	42	26.3	39		0.033	25.8	25.8		25.2	0	9.4	0.46
3.75	0.25	1.7	16:0	00:00:00	0	15.2	26.2	23		0.045	25.7	25.7		24.7	0	7.9	0.37
0.75	0.75	1.7	17:0	00:42:17	0	4.7	26.1	8		0.043	25.6	25.6		24.2	0	6.7	0.29
1.75	0.75	1.7	17:0	00:59:44	0	8.2	26.1	11		0.043	25.6	25.6		24.3	0	7.1	0.31
2.75	0.75	1.7	17:0	01:26:45	0	33.9	26.1	38		0.041	25.6	25.6		25.3	0	9	0.44
3.75	0.75	1.7	16:0	00:06:25	0	11.6	26.2	24		0.043	25.7	25.7		24.6	0	7.7	0.36
0.75	1.25	1.7	16:0	00:36:03	0	12.6	26.2	7		0.04	25.7	25.7		24.2	0	7	0.31
1.75	1.25	1.7	17:0	01:04:45	0	12.4	26.2	12		0.041	25.7	25.7		24.3	0	7.2	0.33
2.25	1.25	1.7	18:0	01:55:30	0	10.3	26.2	21		0.044	25.7	25.7		24.8	0	8	0.38
3.75	1.25	1.7	16:0	00:12:06	0	8	26.2	25		0.045	25.7	25.7		24.8	0	8.1	0.38
0.75	1.75	1.7	16:0	00:30:18	0	4.7	26.1	6		0.044	25.6	25.6		24	0	6.5	0.27
1.75	1.75	1.7	17:0	01:10:08	0	7.1	26.2	13		0.041	25.7	25.7		24.4	0	7.4	0.34
2.75	1.75	1.7	17:0	01:20:48	0	16	26.1	37		0.042	25.6	25.6		25.1	0	8.6	0.42
3.75	1.75	1.7	16:0	00:18:38	0	8	26.3	26		0.045	25.8	25.8		24.7	0	8.2	0.39
0.75	2.25	1.7	16:0	00:24:15	0	6.6	26.2	5		0.044	25.7	25.7		24.4	0	7.4	0.34
1.75	2.25	1.7	17:0	01:15:37	0	4.8	26.2	14		0.043	25.7	25.7		24.6	0	7.8	0.37
2.25	2.25	1.7	18:0	01:49:16	0	9.6	26.2	20		0.043	25.7	25.7		24.7	0	7.9	0.37
2.75	2.25	1.7	17:0	01:15:37	0	4.8	26.2	36		0.043	25.7	25.7		24.6	0	7.8	0.37
3.75	2.25	1.7	16:0	00:24:15	0	6.6	26.2	27		0.044	25.7	25.7		24.4	0	7.4	0.34
0.75	2.75	1.7	16:0	00:18:38	0	8	26.3	4		0.045	25.8	25.8		24.7	0	8.2	0.39
1.75	2.75	1.7	17:0	01:20:48	0	16	26.1	15		0.042	25.6	25.6		25.1	0	8.6	0.42
2.75	2.75	1.7	17:0	01:10:08	0	7.1	26.2	35		0.041	25.7	25.7		24.4	0	7.4	0.34
3.75	2.75	1.7	16:0	00:30:18	0	4.7	26.1	28		0.044	25.6	25.6		24	0	6.5	0.27
0.75	3.25	1.7	16:0	00:12:06	0	8	26.2	3		0.045	25.7	25.7		24.8	0	8.1	0.38
2.25	3.25	1.7	18:0	01:43:37	0	18.2	26.3	19		0.041	25.8	25.8		25	0	8.9	0.43
2.75	3.25	1.7	17:0	01:04:45	0	12.4	26.2	34		0.041	25.7	25.7		24.3	0	7.2	0.33
3.75	3.25	1.7	16:0	00:36:03	0	12.6	26.2	29		0.04	25.7	25.7		24.2	0	7	0.31
0.75	3.75	1.7	16:0	00:06:25	0	11.6	26.2	2		0.043	25.7	25.7		24.6	0	7.7	0.36
1.75	3.75	1.7	17:0	01:26:45	0	33.9	26.1	16		0.041	25.6	25.6		25.3	0	9	0.44
2.75	3.75	1.7	17:0	00:59:44	0	8.2	26.1	33		0.043	25.6	25.6		24.3	0	7.1	0.31
3.75	3.75	1.7	17:0	00:42:17	0	4.7	26.1	30		0.043	25.6	25.6		24.2	0	6.7	0.29
0.75	4.25	1.7	16:0	00:00:00	0	15.2	26.2	1		0.045	25.7	25.7		24.7	0	7.9	0.37
1.75	4.25	1.7	17:0	01:32:05	0	42	26.3	17		0.033	25.8	25.8		25.2	0	9.4	0.46
2.25	4.25	1.7	17:0	01:37:47	0	20.9	26.2	18		0.045	25.7	25.7		25	0	8.6	0.42
2.75	4.25	1.7	17:0	00:53:42	0	8.4	26.2	32		0.042	25.7	25.7		23.9	0	6.6	0.28
3.75	4.25	1.7	17:0	00:48:05	0	15.2	26.1	31		0.04	25.6	25.6		23.7	0	6.1	0.23
49.3	49.3	1.7	18:0	02:00:36	0	22.9	26	22		0.043	25.5	25.5		24.6	0	7.3	0.33
0.75	0.25	2.1	17:0	00:48:05	0	27.9	26.3	9		0.042	26	26		23.7	0	6.8	0.29
1.75	0.25	2.1	17:0	00:53:42	0.1	29.2	26	10		0.052	25.7	25.7		23.9	0.68	6.6	0.28
2.75	0.25	2.1	17:0	01:32:05	0	54.4	26.2	39		0.043	25.9	25.9		25.2	0	9.8	0.48
3.75	0.25	2.1	16:0	00:00:00	0	18.6	26.4	23		0.047	26.1	26.1		24.7	0	9	0.44
0.75	0.75	2.1	17:0	00:42:17	0.1	28.5	26	8		0.053	25.7	25.7		24.2	0.86	6.9	0.31
1.75	0.75	2.1	17:0	00:59:44	0	28.4	26.3	11		0.044	26	26		24.3	0	8	0.38
2.75	0.75	2.1	17:0	01:26:45	0.1	43.4	25.8	38		0.067	25.5	25.5		25.3	2.82	8.7	0.42
3.75	0.75	2.1	16:0	00:06:25	0	28.1	26.2	24		0.049	25.9	25.9		24.6	0	8.2	0.39
0.75	1.25	2.1	16:0	00:36:03	0	12.6	26.4	7		0.046	26.1	26.1		24.2	0	7.9	0.37

1.75	1.25	2.1	17:0	01:04:45	0	18.5	26.2	12		0.044	25.9	25.9		24.3	0	7.7	0.36
2.25	1.25	2.1	18:0	01:55:30	0	40.5	26.2	21		0.037	25.9	25.9		24.8	0	8.6	0.41
3.75	1.25	2.1	16:0	00:12:06	0	12.3	26.3	25		0.047	26	26		24.8	0	8.9	0.43
0.75	1.75	2.1	16:0	00:30:18	0.1	24.7	26.2	6		0.057	25.9	25.9		24	1.36	7.1	0.32
1.75	1.75	2.1	17:0	01:10:08	0	13	26.2	13		0.045	25.9	25.9		24.4	0	7.9	0.37
2.75	1.75	2.1	17:0	01:20:48	0	20.4	26.1	37		0.049	25.8	25.8		25.1	0	9.2	0.45
3.75	1.75	2.1	16:0	00:18:38	0	26.9	26.5	26		0.049	26.2	26.2		24.7	0	9.3	0.46
0.75	2.25	2.1	16:0	00:24:15	0	16.5	26.2	5		0.047	25.9	25.9		24.4	0	7.9	0.37
1.75	2.25	2.1	17:0	01:15:37	0	18.9	26.1	14		0.048	25.8	25.8		24.6	0	8.1	0.38
2.25	2.25	2.1	18:0	01:49:16	0	32	26.2	20		0.046	25.9	25.9		24.7	0	8.4	0.41
2.75	2.25	2.1	17:0	01:15:37	0	18.9	26.1	36		0.048	25.8	25.8		24.6	0	8.1	0.38
3.75	2.25	2.1	16:0	00:24:15	0	16.5	26.2	27		0.047	25.9	25.9		24.4	0	7.9	0.37
0.75	2.75	2.1	16:0	00:18:38	0	26.9	26.5	4		0.049	26.2	26.2		24.7	0	9.3	0.46
1.75	2.75	2.1	17:0	01:20:48	0	20.4	26.1	15		0.049	25.8	25.8		25.1	0	9.2	0.45
2.75	2.75	2.1	17:0	01:10:08	0	13	26.2	35		0.045	25.9	25.9		24.4	0	7.9	0.37
3.75	2.75	2.1	16:0	00:30:18	0.1	24.7	26.2	28		0.057	25.9	25.9		24	1.36	7.1	0.32
0.75	3.25	2.1	16:0	00:12:06	0	12.3	26.3	3		0.047	26	26		24.8	0	8.9	0.43
2.25	3.25	2.1	18:0	01:43:37	0	33.3	26.2	19		0.043	25.9	25.9		25	0	9.2	0.45
2.75	3.25	2.1	17:0	01:04:45	0	18.5	26.2	34		0.044	25.9	25.9		24.3	0	7.7	0.36
3.75	3.25	2.1	16:0	00:36:03	0	12.6	26.4	29		0.046	26.1	26.1		24.2	0	7.9	0.37
0.75	3.75	2.1	16:0	00:06:25	0	28.1	26.2	2		0.049	25.9	25.9		24.6	0	8.2	0.39
1.75	3.75	2.1	17:0	01:26:45	0.1	43.4	25.8	16		0.067	25.5	25.5		25.3	2.82	8.7	0.42
2.75	3.75	2.1	17:0	00:59:44	0	28.4	26.3	33		0.044	26	26		24.3	0	8	0.38
3.75	3.75	2.1	17:0	00:42:17	0.1	28.5	26	30		0.053	25.7	25.7		24.2	0.86	6.9	0.31
0.75	4.25	2.1	16:0	00:00:00	0	18.6	26.4	1		0.047	26.1	26.1		24.7	0	9	0.44
1.75	4.25	2.1	17:0	01:32:05	0	54.4	26.2	17		0.043	25.9	25.9		25.2	0	9.8	0.48
2.25	4.25	2.1	17:0	01:37:47	0	47.3	26.1	18		0.045	25.8	25.8		25	0	8.9	0.43
2.75	4.25	2.1	17:0	00:53:42	0.1	29.2	26	32		0.052	25.7	25.7		23.9	0.68	6.6	0.28
3.75	4.25	2.1	17:0	00:48:05	0	27.9	26.3	31		0.042	26	26		23.7	0	6.8	0.29
49.3	49.3	2.1	18:0	02:00:36	0	41.8	25.9	22		0.042	25.6	25.6		24.6	0	7.5	0.35
0.75	0.25	2.6	17:0	00:48:05	0	13.1	26.8	9		0.032	26.3	26.3		23.7	0	7.4	0.34
1.75	0.25	2.6	17:0	00:53:42	0	36	26.7	10		0.032	26.2	26.2		23.9	0	7.6	0.35
2.75	0.25	2.6	17:0	01:32:05	0.1	32.7	26	39		0.083	25.5	25.5		25.2	4.24	8.5	0.41
3.75	0.25	2.6	16:0	00:00:00	0	35.2	26.9	23		0.026	26.4	26.4		24.7	0	9.9	0.48
0.75	0.75	2.6	17:0	00:42:17	0	17.1	26.8	8		0.027	26.3	26.3		24.2	0	8.3	0.4
1.75	0.75	2.6	17:0	00:59:44	0	28.4	26.7	11		0.028	26.2	26.2		24.3	0	8.5	0.41
2.75	0.75	2.6	17:0	01:26:45	0.1	20.6	25.7	38		0.136	25.2	25.2		25.3	8.06	6.1	0.23
3.75	0.75	2.6	16:0	00:06:25	0.1	40.6	26.4	24		0.043	25.9	25.9		24.6	0	8.2	0.39
0.75	1.25	2.6	16:0	00:36:03	0	17.1	26.8	7		0.038	26.3	26.3		24.2	0	8.4	0.4
1.75	1.25	2.6	17:0	01:04:45	0.1	23.6	26.6	12		0.052	26.1	26.1		24.3	0.53	8.2	0.39
2.25	1.25	2.6	18:0	01:55:30	0.1	19.1	26.1	21		0.071	25.6	25.6		24.8	2.75	7.8	0.37
3.75	1.25	2.6	16:0	00:12:06	0.1	43.3	26.3	25		0.044	25.8	25.8		24.8	0	8.3	0.4
0.75	1.75	2.6	16:0	00:30:18	0	22.1	26.8	6		0.029	26.3	26.3		24	0	8	0.38
1.75	1.75	2.6	17:0	01:10:08	0	27.9	26.4	13		0.037	25.9	25.9		24.4	0	7.9	0.37
2.75	1.75	2.6	17:0	01:20:48	0.1	31	26.1	37		0.046	25.6	25.6		25.1	0	8.6	0.42
3.75	1.75	2.6	16:0	00:18:38	0	27.1	26.8	26		0.037	26.3	26.3		24.7	0	9.6	0.47
0.75	2.25	2.6	16:0	00:24:15	0	20.3	26.8	5		0.034	26.3	26.3		24.4	0	8.9	0.43
1.75	2.25	2.6	17:0	01:15:37	0.1	32.5	26	14		0.054	25.5	25.5		24.6	1.03	7.3	0.34
2.25	2.25	2.6	18:0	01:49:16	0	28.5	26.8	20		0.035	26.3	26.3		24.7	0	9.6	0.47
2.75	2.25	2.6	17:0	01:15:37	0.1	32.5	26	36		0.054	25.5	25.5		24.6	1.03	7.3	0.34
3.75	2.25	2.6	16:0	00:24:15	0	20.3	26.8	27		0.034	26.3	26.3		24.4	0	8.9	0.43
0.75	2.75	2.6	16:0	00:18:38	0	27.1	26.8	4		0.037	26.3	26.3		24.7	0	9.6	0.47
1.75	2.75	2.6	17:0	01:20:48	0.1	31	26.1	15		0.046	25.6	25.6		25.1	0	8.6	0.42
2.75	2.75	2.6	17:0	01:10:08	0	27.9	26.4	35		0.037	25.9	25.9		24.4	0	7.9	0.37
3.75	2.75	2.6	16:0	00:30:18	0	22.1	26.8	28		0.029	26.3	26.3		24	0	8	0.38
0.75	3.25	2.6	16:0	00:12:06	0.1	43.3	26.3	3		0.044	25.8	25.8		24.8	0	8.3	0.4
2.25	3.25	2.6	18:0	01:43:37	0.1	25	26.2	19		0.059	25.7	25.7		25	1.7	8.6	0.42
2.75	3.25	2.6	17:0	01:04:45	0.1	23.6	26.6	34		0.052	26.1	26.1		24.3	0.53	8.2	0.39
3.75	3.25	2.6	16:0	00:36:03	0	17.1	26.8	29		0.038	26.3	26.3		24.2	0	8.4	0.4
0.75	3.75	2.6	16:0	00:06:25	0.1	40.6	26.4	2		0.043	25.9	25.9		24.6	0	8.2	0.39
1.75	3.75	2.6	17:0	01:26:45	0.1	20.6	25.7	16		0.136	25.2	25.2		25.3	8.06	6.1	0.23
2.75	3.75	2.6	17:0	00:59:44	0	28.4	26.7	33		0.028	26.2	26.2		24.3	0	8.5	0.41
3.75	3.75	2.6	17:0	00:42:17	0	17.1	26.8	30		0.027	26.3	26.3		24.2	0	8.3	0.4
0.75	4.25	2.6	16:0	00:00:00	0	35.2	26.9	1		0.026	26.4	26.4		24.7	0	9.9	0.48
1.75	4.25	2.6	17:0	01:32:05	0.1	32.7	26	17		0.083	25.5	25.5		25.2	4.24	8.5	0.41

2.25	4.25	2.6	17:0	01:37:47	0.1	30.9	26.7	18		0.043	26.2	26.2		25	0	10	0.5
2.75	4.25	2.6	17:0	00:53:42	0	36	26.7	32		0.032	26.2	26.2		23.9	0	7.6	0.35
3.75	4.25	2.6	17:0	00:48:05	0	13.1	26.8	31		0.032	26.3	26.3		23.7	0	7.4	0.34
49.3	49.3	2.6	18:0	02:00:36	0	40.6	26.7	22		0.03	26.2	26.2		24.6	0	9	0.44
0.25	0.25	0.1	17:0	00:48:05	0.1	10.8	19.6	31		0.051	19.2	19.2		23.7	0.47	20	-0.8
1.25	0.25	0.1	17:0	01:32:05	0.1	9.1	20.1	39		0.112	19.7	19.7		25.2	8.97	11	-0.6
2.25	0.25	0.1	18:0	02:00:36	0.1	23.8	21.3	22		0.067	20.9	20.9		24.6	3.91	8.9	-0.4
3.25	0.25	0.1	17:0	00:53:42	0.1	19.7	22	10		0.058	21.6	21.6		23.9	2.25	8.2	-0.4
4.25	0.25	0.1	17:0	00:48:05	0.1	10.8	19.6	9		0.051	19.2	19.2		23.7	0.47	20	-0.8
0.25	0.75	0.1	17:0	00:42:17	0	6	19.7	30		0.045	19.3	19.3		24.2	0	17	-0.8
1.25	0.75	0.1	17:0	00:59:44	0.1	24.5	21.8	33		0.063	21.4	21.4		24.3	3.1	7.9	-0.4
1.25	0.75	0.1	17:0	01:26:45	0.1	12.6	21.5	38		0.092	21.1	21.1		25.3	6.47	7	-0.3
2.25	0.75	0.1	18:0	01:55:30	0.1	20.2	22.2	21		0.069	21.7	21.7		24.8	3.88	6.6	-0.3
3.25	0.75	0.1	17:0	00:59:44	0.1	24.5	21.8	11		0.063	21.4	21.4		24.3	3.1	7.9	-0.4
4.25	0.75	0.1	17:0	00:42:17	0	6	19.7	8		0.045	19.3	19.3		24.2	0	17	-0.8
0.25	1.25	0.1	16:0	00:36:03	0	8.7	19.7	29		0.044	19.3	19.3		24.2	0	17	-0.8
1.25	1.25	0.1	17:0	01:20:48	0.1	13.5	20.3	37		0.097	19.9	19.9		25.1	7.63	11	-0.5
4.25	1.25	0.1	16:0	00:36:03	0	8.7	19.7	7		0.044	19.3	19.3		24.2	0	17	-0.8
0.25	1.75	0.1	16:0	00:30:18	0.1	16.1	19.5	28		0.07	19.1	19.1		24	4.73	19	-0.8
1.25	1.75	0.1	17:0	01:15:37	0.1	5.1	20.7	36		0.114	20.3	20.3		24.6	8.38	11	-0.5
2.25	1.75	0.1	18:0	01:49:16	0.1	21.2	21.7	20		0.063	21.3	21.3		24.7	3.06	7.6	-0.4
3.25	1.75	0.1	17:0	01:04:45	0.1	24.5	21.6	12		0.101	21.2	21.2		24.3	8.2	8.5	-0.4
4.25	1.75	0.1	16:0	00:30:18	0.1	16.1	19.5	6		0.07	19.1	19.1		24	4.73	19	-0.8
0.25	2.25	0.1	16:0	00:24:15	0.2	15	18.7	27		0.198	18.3	18.3		24.4	20.3	37	-1.2
1.25	2.25	0.1	17:0	01:10:08	0.1	8.9	20.8	35		0.114	20.4	20.4		24.4	8.71	11	-0.6
3.25	2.25	0.1	17:0	01:10:08	0.1	8.9	20.8	13		0.114	20.4	20.4		24.4	8.71	11	-0.6
4.25	2.25	0.1	16:0	00:24:15	0.2	15	18.7	5		0.198	18.3	18.3		24.4	20.3	37	-1.2
0.25	2.75	0.1	16:0	00:18:38	0.1	2.9	19.9	26		0.064	19.5	19.5		24.7	3.26	14	-0.7
1.25	2.75	0.1	17:0	01:04:45	0.1	24.5	21.6	34		0.101	21.2	21.2		24.3	8.2	8.5	-0.4
2.25	2.75	0.1	18:0	01:43:37	0.1	16.8	21.9	19		0.06	21.5	21.5		25	2.59	6.6	-0.3
3.25	2.75	0.1	17:0	01:15:37	0.1	5.1	20.7	14		0.114	20.3	20.3		24.6	8.38	11	-0.5
4.25	2.75	0.1	16:0	00:18:38	0.1	2.9	19.9	4		0.064	19.5	19.5		24.7	3.26	14	-0.7
0.25	3.25	0.1	16:0	00:12:06	0.1	0	20.3	25		0.07	19.9	19.9		24.8	3.95	12	-0.6
3.25	3.25	0.1	17:0	01:20:48	0.1	13.5	20.3	15		0.097	19.9	19.9		25.1	7.63	11	-0.5
4.25	3.25	0.1	16:0	00:12:06	0.1	0	20.3	3		0.07	19.9	19.9		24.8	3.95	12	-0.6
0.25	3.75	0.1	16:0	00:06:25	0.1	5.6	21.2	24		0.048	20.8	20.8		24.6	0	9.2	-0.4
2.25	3.75	0.1	17:0	01:37:47	0.1	21.5	21.8	18		0.076	21.4	21.4		25	4.88	6.7	-0.3
3.25	3.75	0.1	17:0	01:26:45	0.1	12.6	21.5	16		0.092	21.1	21.1		25.3	6.47	7	-0.3
4.25	3.75	0.1	16:0	00:06:25	0.1	5.6	21.2	2		0.048	20.8	20.8		24.6	0	9.2	-0.4
0.25	4.25	0.1	16:0	00:00:00	0.1	10.8	20.2	23		0.109	19.8	19.8		24.7	8.75	13	-0.6
1.25	4.25	0.1	17:0	00:53:42	0.1	19.7	22	32		0.058	21.6	21.6		23.9	2.25	8.2	-0.4
3.25	4.25	0.1	17:0	01:32:05	0.1	9.1	20.1	17		0.112	19.7	19.7		25.2	8.97	11	-0.6
4.25	4.25	0.1	16:0	00:00:00	0.1	10.8	20.2	1		0.109	19.8	19.8		24.7	8.75	13	-0.6
0.25	0.25	0.6	17:0	00:48:05	0	24.7	22.4	31	22.7	0.038	21.8	21.8	22.73	23.3	0	9	-0.4
1.25	0.25	0.6	17:0	01:32:05	0.1	22.1	22	39	22.9	0.047	21.4	21.4	22.86	23.9	0	8.9	-0.4
2.25	0.25	0.6	18:0	02:00:36	0	29.1	22.5	22	23	0.032	21.9	21.9	22.99	23.6	0	8	-0.4
3.25	0.25	0.6	17:0	00:53:42	0.1	22.9	21.9	10	23.2	0.076	21.3	21.3	23.2	24.9	4.95	7.2	-0.3
4.25	0.25	0.6	17:0	00:48:05	0	24.7	22.4	9	22.7	0.038	21.8	21.8	22.73	23.3	0	9	-0.4
0.25	0.75	0.6	17:0	00:42:17	0	17.5	22.6	30	22.9	0.037	22	22	22.9	23.5	0	8.1	-0.4
1.25	0.75	0.6	17:0	01:26:45	0	10.3	22.8	38	22.9	0.035	22.2	22.2	22.87	23.3	0	7.9	-0.4
2.25	0.75	0.6	18:0	01:55:30	0	24.5	22.6	21	22.8	0.035	22	22	22.81	23.3	0	8.4	-0.4
3.25	0.75	0.6	17:0	00:59:44	0.1	27.5	22	11	23.4	0.079	21.4	21.4	23.41	25.2	5.49	6.5	-0.3
4.25	0.75	0.6	17:0	00:42:17	0	17.5	22.6	8	22.9	0.037	22	22	22.9	23.5	0	8.1	-0.4
0.25	1.25	0.6	16:0	00:36:03	0.1	11.4	22.6	29	23	0.041	22	22	23	23.6	0	7.7	-0.4
1.25	1.25	0.6	17:0	01:20:48	0	6.2	22.5	37	22.9	0.037	21.9	21.9	22.88	23.5	0	8.3	-0.4
4.25	1.25	0.6	16:0	00:36:03	0.1	11.4	22.6	7	23	0.041	22	22	23	23.6	0	7.7	-0.4
0.25	1.75	0.6	16:0	00:30:18	0	16.4	22.7	28	22.7	0.037	22.1	22.1	22.71	23.1	0	8.6	-0.4
1.25	1.75	0.6	17:0	01:15:37	0.1	12.3	22.4	36	23.2	0.042	21.8	21.8	23.18	24.1	0	7.4	-0.3
2.25	1.75	0.6	18:0	01:49:16	0.1	20.9	21.6	20	22.8	0.076	21	21	22.76	24.3	4.99	9.2	-0.4
3.25	1.75	0.6	17:0	01:04:45	0.1	21.6	21.8	12	23.3	0.055	21.2	21.2	23.29	24.8	1.76	7.5	-0.3
4.25	1.75	0.6	16:0	00:30:18	0	16.4	22.7	6	22.7	0.037	22.1	22.1	22.71	23.1	0	8.6	-0.4
0.25	2.25	0.6	16:0	00:24:15	0	27.7	22.2	27	22.8	0.038	21.6	21.6	22.76	23.5	0	9.2	-0.4
1.25	2.25	0.6	17:0	01:10:08	0.1	20.1	22.2	35	23.2	0.049	21.6	21.6	23.17	24.3	0	7.6	-0.4
3.25	2.25	0.6	17:0	01:10:08	0.1	20.1	22.2	13	23.2	0.049	21.6	21.6	23.17	24.3	0	7.6	-0.4
4.25	2.25	0.6	16:0	00:24:15	0	27.7	22.2	5	22.8	0.038	21.6	21.6	22.76	23.5	0	9.2	-0.4

0.25	2.75	0.6	16:0	00:18:38	0	48.1	22.3	26	22.9	0.023	21.7	21.7	22.87	23.4	0	9	-0.4
1.25	2.75	0.6	17:0	01:04:45	0.1	21.6	21.8	34	23.3	0.055	21.2	21.2	23.29	24.8	1.76	7.5	-0.3
2.25	2.75	0.6	18:0	01:43:37	0.1	24.8	21.5	19	22.9	0.06	20.9	20.9	22.86	24.4	2.83	9.3	-0.5
3.25	2.75	0.6	17:0	01:15:37	0.1	12.3	22.4	14	23.2	0.042	21.8	21.8	23.18	24.1	0	7.4	-0.3
4.25	2.75	0.6	16:0	00:18:38	0	48.1	22.3	4	22.9	0.023	21.7	21.7	22.87	23.4	0	9	-0.4
0.25	3.25	0.6	16:0	00:12:06	0	17.5	22.5	25	22.8	0.034	21.9	21.9	22.76	23.3	0	8.8	-0.4
3.25	3.25	0.6	17:0	01:20:48	0	6.2	22.5	15	22.9	0.037	21.9	21.9	22.88	23.5	0	8.3	-0.4
4.25	3.25	0.6	16:0	00:12:06	0	17.5	22.5	3	22.8	0.034	21.9	21.9	22.76	23.3	0	8.8	-0.4
0.25	3.75	0.6	16:0	00:06:25	0	8.8	22.4	24	22.6	0.037	21.8	21.8	22.6	23.1	0	9.5	-0.5
1.25	3.75	0.6	17:0	00:59:44	0.1	27.5	22	33	23.4	0.079	21.4	21.4	23.41	25.2	5.49	6.5	-0.3
2.25	3.75	0.6	17:0	01:37:47	0	55.4	22.2	18	22.9	0.036	21.6	21.6	22.91	23.7	0	8.7	-0.4
3.25	3.75	0.6	17:0	01:26:45	0	10.3	22.8	16	22.9	0.035	22.2	22.2	22.87	23.3	0	7.9	-0.4
4.25	3.75	0.6	16:0	00:06:25	0	8.8	22.4	2	22.6	0.037	21.8	21.8	22.6	23.1	0	9.5	-0.5
0.25	4.25	0.6	16:0	00:00:00	0.1	8.1	22.5	23	22.7	0.041	21.9	21.9	22.68	23.2	0	8.9	-0.4
1.25	4.25	0.6	17:0	00:53:42	0.1	22.9	21.9	32	23.2	0.076	21.3	21.3	23.2	24.9	4.95	7.2	-0.3
3.25	4.25	0.6	17:0	01:32:05	0.1	22.1	22	17	22.9	0.047	21.4	21.4	22.86	23.9	0	8.9	-0.4
4.25	4.25	0.6	16:0	00:00:00	0.1	8.1	22.5	1	22.7	0.041	21.9	21.9	22.68	23.2	0	8.9	-0.4
0.25	0.25	1.1	17:0	00:48:05	0	17.9	23.7	31	23.8	0.042	23.3	23.3	23.83	24.2	0	5.1	-0.1
1.25	0.25	1.1	17:0	01:32:05	0	16.9	23.9	39	23.7	0.039	23.5	23.5	23.7	23.8	0	5.2	-0.1
2.25	0.25	1.1	18:0	02:00:36	0	48.9	24	22	23.9	0.031	23.6	23.6	23.92	24.1	0	5	-0
3.25	0.25	1.1	17:0	00:53:42	0.1	35.5	22.8	10	24.8	0.056	22.4	22.4	24.75	26.5	1.97	5.1	0.07
4.25	0.25	1.1	17:0	00:48:05	0	17.9	23.7	9	23.8	0.042	23.3	23.3	23.83	24.2	0	5.1	-0.1
0.25	0.75	1.1	17:0	00:42:17	0	7.2	23.9	30	23.9	0.039	23.5	23.5	23.91	24.2	0	5.1	-0
1.25	0.75	1.1	17:0	01:26:45	0	10.3	23.9	38	23.7	0.039	23.5	23.5	23.72	23.9	0	5.2	-0.1
2.25	0.75	1.1	18:0	01:55:30	0	9.3	23.9	21	24	0.043	23.5	23.5	23.96	24.3	0	5	-0
3.25	0.75	1.1	17:0	00:59:44	0	31.4	24	11	24.7	0.045	23.6	23.6	24.74	25.5	0	5.4	0.14
4.25	0.75	1.1	17:0	00:42:17	0	7.2	23.9	8	23.9	0.039	23.5	23.5	23.91	24.2	0	5.1	-0
0.25	1.25	1.1	16:0	00:36:03	0	16.1	24	29	24.1	0.039	23.6	23.6	24.08	24.4	0	5	-0
1.25	1.25	1.1	17:0	01:20:48	0	12.9	23.9	37	23.8	0.041	23.5	23.5	23.77	23.9	0	5.1	-0.1
4.25	1.25	1.1	16:0	00:36:03	0	16.1	24	7	24.1	0.039	23.6	23.6	24.08	24.4	0	5	-0
0.25	1.75	1.1	16:0	00:30:18	0	12.6	23.9	28	23.8	0.039	23.5	23.5	23.83	24	0	5.1	-0.1
1.25	1.75	1.1	17:0	01:15:37	0	6.7	24	36	24.1	0.042	23.6	23.6	24.09	24.4	0	5	0
2.25	1.75	1.1	18:0	01:49:16	0	9.4	23.9	20	24	0.043	23.5	23.5	24.03	24.4	0	5	-0
3.25	1.75	1.1	17:0	01:04:45	0	15	24.2	12	24.6	0.044	23.8	23.8	24.57	25.1	0	5.3	0.12
4.25	1.75	1.1	16:0	00:30:18	0	12.6	23.9	6	23.8	0.039	23.5	23.5	23.83	24	0	5.1	-0.1
0.25	2.25	1.1	16:0	00:24:15	0	9.4	23.9	27	23.8	0.043	23.5	23.5	23.79	24	0	5.1	-0.1
1.25	2.25	1.1	17:0	01:10:08	0	12.1	24.1	35	24.4	0.041	23.7	23.7	24.38	24.8	0	5.1	0.07
3.25	2.25	1.1	17:0	01:10:08	0	12.1	24.1	13	24.4	0.041	23.7	23.7	24.38	24.8	0	5.1	0.07
4.25	2.25	1.1	16:0	00:24:15	0	9.4	23.9	5	23.8	0.043	23.5	23.5	23.79	24	0	5.1	-0.1
0.25	2.75	1.1	16:0	00:18:38	0	8.4	24	26	23.8	0.041	23.6	23.6	23.76	23.9	0	5.1	-0.1
1.25	2.75	1.1	17:0	01:04:45	0	15	24.2	34	24.6	0.044	23.8	23.8	24.57	25.1	0	5.3	0.12
2.25	2.75	1.1	18:0	01:43:37	0	8	23.8	19	24	0.043	23.4	23.4	24.01	24.4	0	5	-0
3.25	2.75	1.1	17:0	01:15:37	0	6.7	24	14	24.1	0.042	23.6	23.6	24.09	24.4	0	5	0
4.25	2.75	1.1	16:0	00:18:38	0	8.4	24	4	23.8	0.041	23.6	23.6	23.76	23.9	0	5.1	-0.1
0.25	3.25	1.1	16:0	00:12:06	0	10.9	24	25	23.7	0.041	23.6	23.6	23.66	23.7	0	5.2	-0.1
3.25	3.25	1.1	17:0	01:20:48	0	12.9	23.9	15	23.8	0.041	23.5	23.5	23.77	23.9	0	5.1	-0.1
4.25	3.25	1.1	16:0	00:12:06	0	10.9	24	3	23.7	0.041	23.6	23.6	23.66	23.7	0	5.2	-0.1
0.25	3.75	1.1	16:0	00:06:25	0	7	23.9	24	23.6	0.041	23.5	23.5	23.56	23.6	0	5.3	-0.1
1.25	3.75	1.1	17:0	00:59:44	0	31.4	24	33	24.7	0.045	23.6	23.6	24.74	25.5	0	5.4	0.14
2.25	3.75	1.1	17:0	01:37:47	0	12.8	23.9	18	23.8	0.042	23.5	23.5	23.82	24	0	5.1	-0.1
3.25	3.75	1.1	17:0	01:26:45	0	10.3	23.9	16	23.7	0.039	23.5	23.5	23.72	23.9	0	5.2	-0.1
4.25	3.75	1.1	16:0	00:06:25	0	7	23.9	2	23.6	0.041	23.5	23.5	23.56	23.6	0	5.3	-0.1
0.25	4.25	1.1	16:0	00:00:00	0	0	23.9	23	23.7	0.041	23.5	23.5	23.67	23.8	0	5.2	-0.1
1.25	4.25	1.1	17:0	00:53:42	0.1	35.5	22.8	32	24.8	0.056	22.4	22.4	24.75	26.5	1.97	5.1	0.07
3.25	4.25	1.1	17:0	01:32:05	0	16.9	23.9	17	23.7	0.039	23.5	23.5	23.7	23.8	0	5.2	-0.1
4.25	4.25	1.1	16:0	00:00:00	0	0	23.9	1	23.7	0.041	23.5	23.5	23.67	23.8	0	5.2	-0.1
0.25	0.25	1.7	17:0	00:48:05	0	14.8	25.7	31		0.037	25.3	25.3		24.2	0	6.2	0.24
1.25	0.25	1.7	17:0	01:32:05	0	10.9	26	39		0.038	25.6	25.6		23.8	0	6.3	0.25
2.25	0.25	1.7	18:0	02:00:36	0	22.9	26	22		0.043	25.6	25.6		24.1	0	6.7	0.28
3.25	0.25	1.7	17:0	00:53:42	0	53.6	25.8	10		0.03	25.4	25.4		26.5	0	12	0.56
4.25	0.25	1.7	17:0	00:48:05	0	14.8	25.7	9		0.037	25.3	25.3		24.2	0	6.2	0.24
0.25	0.75	1.7	17:0	00:42:17	0	10.9	25.9	30		0.038	25.5	25.5		24.2	0	6.6	0.28
1.25	0.75	1.7	17:0	01:26:45	0	13.3	26	38		0.038	25.6	25.6		23.9	0	6.3	0.25
2.25	0.75	1.7	18:0	01:55:30	0	15.9	26	21		0.043	25.6	25.6		24.3	0	6.9	0.3
3.25	0.75	1.7	17:0	00:59:44	0	70.6	25.7	11		0.019	25.3	25.3		25.5	0	8.6	0.42

4.25	0.75	1.7	17:01	00:42:17	0	10.9	25.9	8		0.038	25.5	25.5		24.2	0	6.6	0.28
0.25	1.25	1.7	16:05	00:36:03	0	11.2	25.9	29		0.037	25.5	25.5		24.4	0	6.9	0.3
1.25	1.25	1.7	17:04	01:20:48	0	7.6	26	37		0.038	25.6	25.6		23.9	0	6.4	0.26
4.25	1.25	1.7	16:05	00:36:03	0	11.2	25.9	7		0.037	25.5	25.5		24.4	0	6.9	0.3
0.25	1.75	1.7	16:04	00:30:18	0	5.5	25.9	28		0.038	25.5	25.5		24	0	6.4	0.26
1.25	1.75	1.7	17:03	01:15:37	0	5.1	26	36		0.04	25.6	25.6		24.4	0	7.2	0.32
2.25	1.75	1.7	18:08	01:49:16	0	10.9	26	20		0.038	25.6	25.6		24.4	0	7.1	0.32
3.25	1.75	1.7	17:02	01:04:45	0	14.2	26.1	12		0.038	25.7	25.7		25.1	0	8.8	0.43
4.25	1.75	1.7	16:04	00:30:18	0	5.5	25.9	6		0.038	25.5	25.5		24	0	6.4	0.26
0.25	2.25	1.7	16:04	00:24:15	0	10.6	26	27		0.039	25.6	25.6		24	0	6.5	0.27
1.25	2.25	1.7	17:02	01:10:08	0	10.6	26	35		0.039	25.6	25.6		24.8	0	7.9	0.38
3.25	2.25	1.7	17:02	01:10:08	0	10.6	26	13		0.039	25.6	25.6		24.8	0	7.9	0.38
4.25	2.25	1.7	16:04	00:24:15	0	10.6	26	5		0.039	25.6	25.6		24	0	6.5	0.27
0.25	2.75	1.7	16:03	00:18:38	0	0	26.1	26		0.04	25.7	25.7		23.9	0	6.5	0.27
1.25	2.75	1.7	17:02	01:04:45	0	14.2	26.1	34		0.038	25.7	25.7		25.1	0	8.8	0.43
2.25	2.75	1.7	18:02	01:43:37	0	7.6	26.1	19		0.038	25.7	25.7		24.4	0	7.4	0.34
3.25	2.75	1.7	17:03	01:15:37	0	5.1	26	14		0.04	25.6	25.6		24.4	0	7.2	0.32
4.25	2.75	1.7	16:03	00:18:38	0	0	26.1	4		0.04	25.7	25.7		23.9	0	6.5	0.27
0.25	3.25	1.7	16:03	00:12:06	0	21	25.8	25		0.033	25.4	25.4		23.7	0	5.8	0.2
3.25	3.25	1.7	17:04	01:20:48	0	7.6	26	15		0.038	25.6	25.6		23.9	0	6.4	0.26
4.25	3.25	1.7	16:03	00:12:06	0	21	25.8	3		0.033	25.4	25.4		23.7	0	5.8	0.2
0.25	3.75	1.7	16:02	00:06:25	0	14.2	25.9	24		0.036	25.5	25.5		23.6	0	5.9	0.2
1.25	3.75	1.7	17:01	00:59:44	0	70.6	25.7	33		0.019	25.3	25.3		25.5	0	8.6	0.42
2.25	3.75	1.7	17:05	01:37:47	0	13.7	26	18		0.037	25.6	25.6		24	0	6.6	0.27
3.25	3.75	1.7	17:04	01:26:45	0	13.3	26	16		0.038	25.6	25.6		23.9	0	6.3	0.25
4.25	3.75	1.7	16:02	00:06:25	0	14.2	25.9	2		0.036	25.5	25.5		23.6	0	5.9	0.2
0.25	4.25	1.7	16:01	00:00:00	0	5.2	26	23		0.04	25.6	25.6		23.8	0	6.2	0.24
1.25	4.25	1.7	17:01	00:53:42	0	53.6	25.8	32		0.03	25.4	25.4		26.5	0	12	0.56
3.25	4.25	1.7	17:05	01:32:05	0	10.9	26	17		0.038	25.6	25.6		23.8	0	6.3	0.25
4.25	4.25	1.7	16:01	00:00:00	0	5.2	26	1		0.04	25.6	25.6		23.8	0	6.2	0.24
0.25	0.25	2.1	17:07	00:48:05	0	35.1	26	31		0.044	25.8	25.8		24.2	0	7.2	0.32
1.25	0.25	2.1	17:05	01:32:05	0.1	39.6	25.6	39		0.051	25.4	25.4		23.8	0.4	6	0.22
2.25	0.25	2.1	18:01	02:00:36	0	41.8	25.9	22		0.042	25.7	25.7		24.1	0	6.9	0.3
3.25	0.25	2.1	17:01	00:53:42	0	42.3	26.1	10		0.041	25.9	25.9		26.5	0	14	0.64
4.25	0.25	2.1	17:07	00:48:05	0	35.1	26	9		0.044	25.8	25.8		24.2	0	7.2	0.32
0.25	0.75	2.1	17:01	00:42:17	0	16.4	26.1	30		0.04	25.9	25.9		24.2	0	7.4	0.34
1.25	0.75	2.1	17:04	01:26:45	0.1	24	26	38		0.055	25.8	25.8		23.9	1.07	6.7	0.28
2.25	0.75	2.1	18:01	01:55:30	0	35.3	25.9	21		0.049	25.7	25.7		24.3	0	7.1	0.32
3.25	0.75	2.1	17:01	00:59:44	0	45.3	26	11		0.046	25.8	25.8		25.5	0	10	0.5
4.25	0.75	2.1	17:01	00:42:17	0	16.4	26.1	8		0.04	25.9	25.9		24.2	0	7.4	0.34
0.25	1.25	2.1	16:05	00:36:03	0	12.1	26.2	29		0.041	26	26		24.4	0	8	0.38
1.25	1.25	2.1	17:04	01:20:48	0.1	18.1	26	37		0.055	25.8	25.8		23.9	1.03	6.8	0.29
4.25	1.25	2.1	16:05	00:36:03	0	12.1	26.2	7		0.041	26	26		24.4	0	8	0.38
0.25	1.75	2.1	16:04	00:30:18	0	25.5	26.1	28		0.032	25.9	25.9		24	0	7.2	0.32
1.25	1.75	2.1	17:03	01:15:37	0	15.4	26.1	36		0.046	25.9	25.9		24.4	0	7.9	0.37
2.25	1.75	2.1	18:08	01:49:16	0	19.8	26	20		0.046	25.8	25.8		24.4	0	7.6	0.35
3.25	1.75	2.1	17:02	01:04:45	0	21.8	26.1	12		0.045	25.9	25.9		25.1	0	9.4	0.46
4.25	1.75	2.1	16:04	00:30:18	0	25.5	26.1	6		0.032	25.9	25.9		24	0	7.2	0.32
0.25	2.25	2.1	16:04	00:24:15	0	20.8	26.1	27		0.038	25.9	25.9		24	0	7.1	0.32
1.25	2.25	2.1	17:02	01:10:08	0	25.5	26.2	35		0.048	26	26		24.8	0	9	0.44
3.25	2.25	2.1	17:02	01:10:08	0	25.5	26.2	13		0.048	26	26		24.8	0	9	0.44
4.25	2.25	2.1	16:04	00:24:15	0	20.8	26.1	5		0.038	25.9	25.9		24	0	7.1	0.32
0.25	2.75	2.1	16:03	00:18:38	0	20.2	26	26		0.039	25.8	25.8		23.9	0	6.7	0.28
1.25	2.75	2.1	17:02	01:04:45	0	21.8	26.1	34		0.045	25.9	25.9		25.1	0	9.4	0.46
2.25	2.75	2.1	18:02	01:43:37	0	18.9	26	19		0.043	25.8	25.8		24.4	0	7.6	0.35
3.25	2.75	2.1	17:03	01:15:37	0	15.4	26.1	14		0.046	25.9	25.9		24.4	0	7.9	0.37
4.25	2.75	2.1	16:03	00:18:38	0	20.2	26	4		0.039	25.8	25.8		23.9	0	6.7	0.28
0.25	3.25	2.1	16:03	00:12:06	0	30.6	26	25		0.036	25.8	25.8		23.7	0	6.4	0.26
3.25	3.25	2.1	17:04	01:20:48	0.1	18.1	26	15		0.055	25.8	25.8		23.9	1.03	6.8	0.29
4.25	3.25	2.1	16:03	00:12:06	0	30.6	26	3		0.036	25.8	25.8		23.7	0	6.4	0.26
0.25	3.75	2.1	16:02	00:06:25	0	16.9	26.2	24		0.042	26	26		23.6	0	6.7	0.28
1.25	3.75	2.1	17:01	00:59:44	0	45.3	26	33		0.046	25.8	25.8		25.5	0	10	0.5
2.25	3.75	2.1	17:05	01:37:47	0.1	21.9	26	18		0.057	25.8	25.8		24	1.31	7	0.31
3.25	3.75	2.1	17:04	01:26:45	0.1	24	26	16		0.055	25.8	25.8		23.9	1.07	6.7	0.28
4.25	3.75	2.1	16:02	00:06:25	0	16.9	26.2	2		0.042	26	26		23.6	0	6.7	0.28

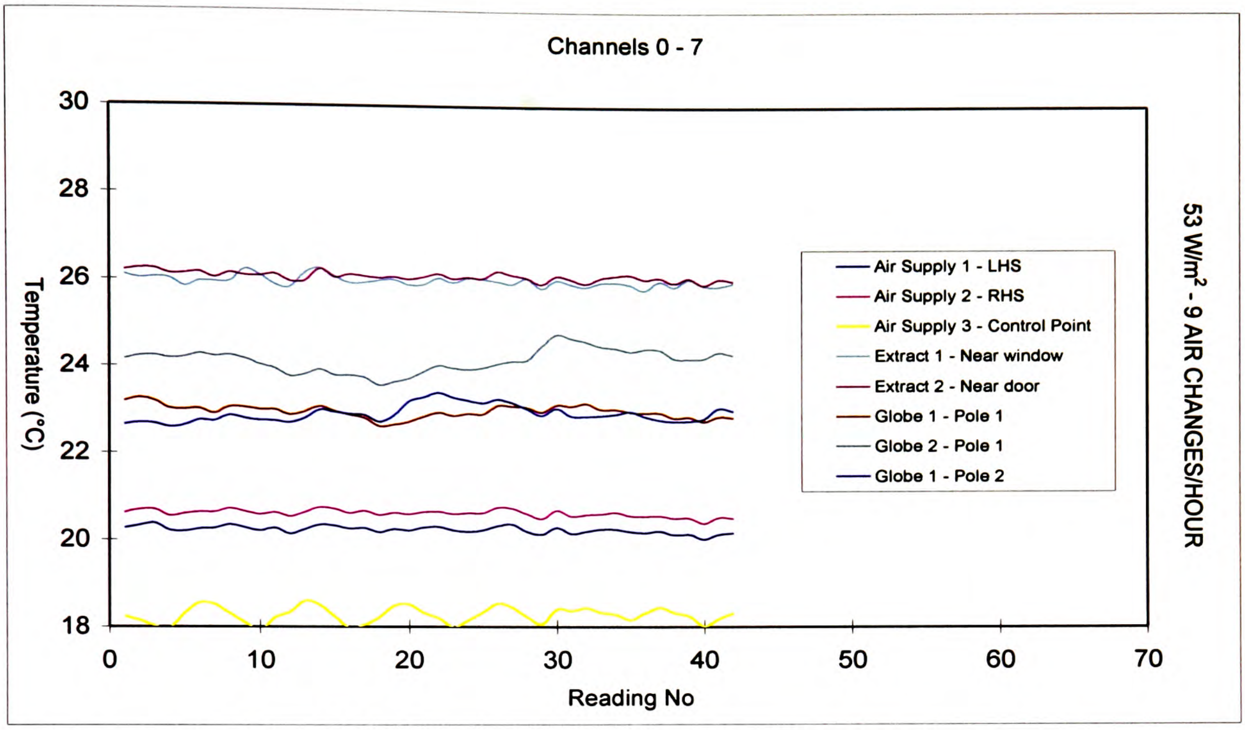
0.25	4.25	2.1	16:0	00:00:00	0.1	31.1	26.3	23		0.056	26.1	26.1		23.8	1.2	7.1	0.32
1.25	4.25	2.1	17:0	00:53:42	0	42.3	26.1	32		0.041	25.9	25.9		26.5	0	14	0.64
3.25	4.25	2.1	17:0	01:32:05	0.1	39.6	25.6	17		0.051	25.4	25.4		23.8	0.4	6	0.22
4.25	4.25	2.1	16:0	00:00:00	0.1	31.1	26.3	1		0.056	26.1	26.1		23.8	1.2	7.1	0.32
0.25	0.25	2.6	17:0	00:48:05	0	30.3	27	31		0.041	26.3	26.3		24.2	0	8.4	0.4
1.25	0.25	2.6	17:0	01:32:05	0	42.9	26.4	39		0.056	25.8	25.8		23.8	1.44	6.6	0.28
2.25	0.25	2.6	18:0	02:00:36	0	40.6	26.7	22		0.049	26	26		24.1	0	7.5	0.35
3.25	0.25	2.6	17:0	00:53:42	0.1	41.8	26.6	10		0.067	25.9	25.9		26.5	2.76	14	0.64
4.25	0.25	2.6	17:0	00:48:05	0	30.3	27	9		0.041	26.3	26.3		24.2	0	8.4	0.4
0.25	0.75	2.6	17:0	00:42:17	0	29.6	26.8	30		0.05	26.1	26.1		24.2	0.18	7.9	0.37
1.25	0.75	2.6	17:0	01:26:45	0	46.2	26.8	38		0.042	26.1	26.1		23.9	0	7.3	0.33
2.25	0.75	2.6	18:0	01:55:30	0.1	40.8	26.7	21		0.059	26	26		24.3	1.79	7.8	0.37
3.25	0.75	2.6	17:0	00:59:44	0.1	26.3	26	11		0.099	25.4	25.4		25.5	5.43	8.1	0.39
4.25	0.75	2.6	17:0	00:42:17	0	29.6	26.8	8		0.05	26.1	26.1		24.2	0.18	7.9	0.37
0.25	1.25	2.6	16:0	00:36:03	0	36.5	26.8	29		0.05	26.1	26.1		24.4	0.18	8.3	0.4
1.25	1.25	2.6	17:0	01:20:48	0	26	26.8	37		0.047	26.1	26.1		23.9	0	7.4	0.34
4.25	1.25	2.6	16:0	00:36:03	0	36.5	26.8	7		0.05	26.1	26.1		24.4	0.18	8.3	0.4
0.25	1.75	2.6	16:0	00:30:18	0	38.5	26.9	28		0.037	26.2	26.2		24	0	7.8	0.37
1.25	1.75	2.6	17:0	01:15:37	0	36.4	26.7	36		0.054	26	26		24.4	1.06	8.1	0.39
2.25	1.75	2.6	18:0	01:49:16	0.1	22.9	26.4	20		0.061	25.8	25.8		24.4	1.87	7.6	0.35
3.25	1.75	2.6	17:0	01:04:45	0.1	36.4	26.4	12		0.084	25.8	25.8		25.1	4.28	8.9	0.43
4.25	1.75	2.6	16:0	00:30:18	0	38.5	26.9	6		0.037	26.2	26.2		24	0	7.8	0.37
0.25	2.25	2.6	16:0	00:24:15	0	32.7	26.8	27		0.042	26.1	26.1		24	0	7.5	0.35
1.25	2.25	2.6	17:0	01:10:08	0.1	33.6	26.2	35		0.067	25.6	25.6		24.8	2.72	7.9	0.38
3.25	2.25	2.6	17:0	01:10:08	0.1	33.6	26.2	13		0.067	25.6	25.6		24.8	2.72	7.9	0.38
4.25	2.25	2.6	16:0	00:24:15	0	32.7	26.8	5		0.042	26.1	26.1		24	0	7.5	0.35
0.25	2.75	2.6	16:0	00:18:38	0	15.6	26.9	26		0.05	26.2	26.2		23.9	0.16	7.5	0.35
1.25	2.75	2.6	17:0	01:04:45	0.1	36.4	26.4	34		0.084	25.8	25.8		25.1	4.28	8.9	0.43
2.25	2.75	2.6	18:0	01:43:37	0.1	18	26.8	19		0.061	26.1	26.1		24.4	1.75	8.4	0.4
3.25	2.75	2.6	17:0	01:15:37	0	36.4	26.7	14		0.054	26	26		24.4	1.06	8.1	0.39
4.25	2.75	2.6	16:0	00:18:38	0	15.6	26.9	4		0.05	26.2	26.2		23.9	0.16	7.5	0.35
0.25	3.25	2.6	16:0	00:12:06	0	22.5	26.8	25		0.041	26.1	26.1		23.7	0	7	0.31
3.25	3.25	2.6	17:0	01:20:48	0	26	26.8	15		0.047	26.1	26.1		23.9	0	7.4	0.34
4.25	3.25	2.6	16:0	00:12:06	0	22.5	26.8	3		0.041	26.1	26.1		23.7	0	7	0.31
0.25	3.75	2.6	16:0	00:06:25	0	14.4	26.8	24		0.051	26.1	26.1		23.6	0.43	6.8	0.3
1.25	3.75	2.6	17:0	00:59:44	0.1	26.3	26	33		0.099	25.4	25.4		25.5	5.43	8.1	0.39
2.25	3.75	2.6	17:0	01:37:47	0.1	34.5	25.8	18		0.091	25.2	25.2		24	5.21	5.7	0.19
3.25	3.75	2.6	17:0	01:26:45	0	46.2	26.8	16		0.042	26.1	26.1		23.9	0	7.3	0.33
4.25	3.75	2.6	16:0	00:06:25	0	14.4	26.8	2		0.051	26.1	26.1		23.6	0.43	6.8	0.3
0.25	4.25	2.6	16:0	00:00:00	0	14.7	26.8	23		0.045	26.1	26.1		23.8	0	7.1	0.32
1.25	4.25	2.6	17:0	00:53:42	0.1	41.8	26.6	32		0.067	25.9	25.9		26.5	2.76	14	0.64
3.25	4.25	2.6	17:0	01:32:05	0	42.9	26.4	17		0.056	25.8	25.8		23.8	1.44	6.6	0.28
4.25	4.25	2.6	16:0	00:00:00	0	14.7	26.8	1		0.045	26.1	26.1		23.8	0	7.1	0.32

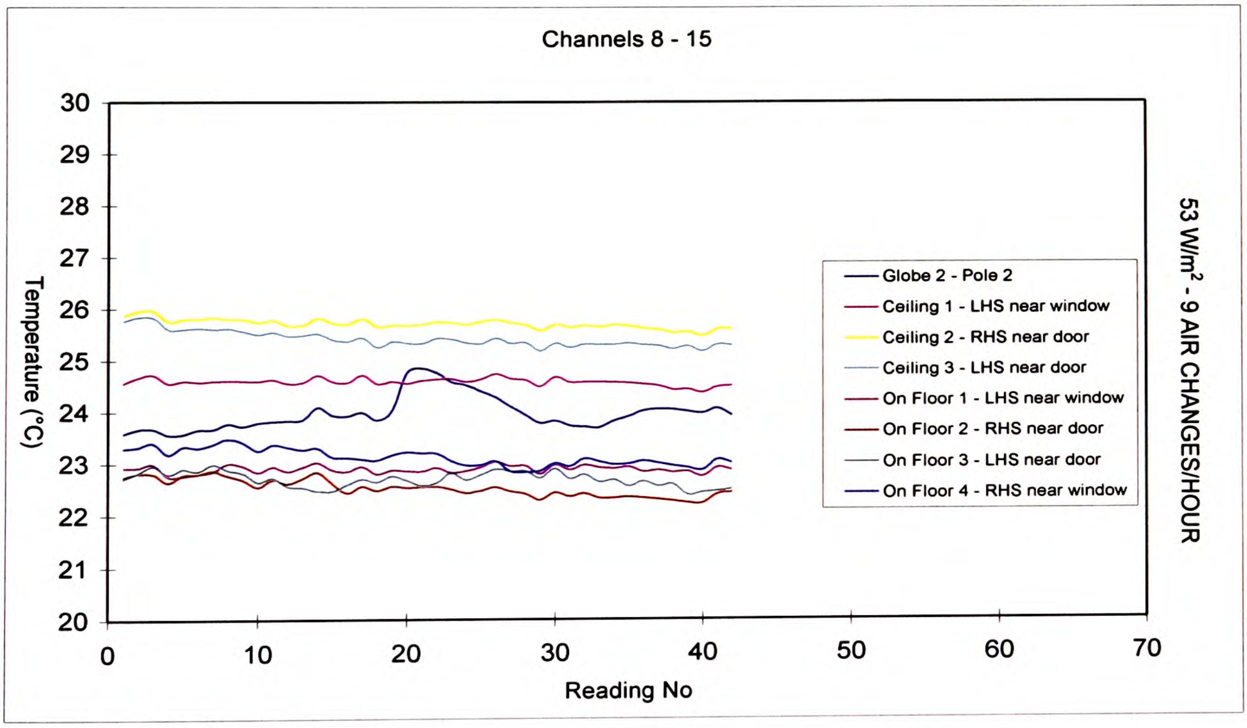
Room Temperature Data (Surface Thermocouples)

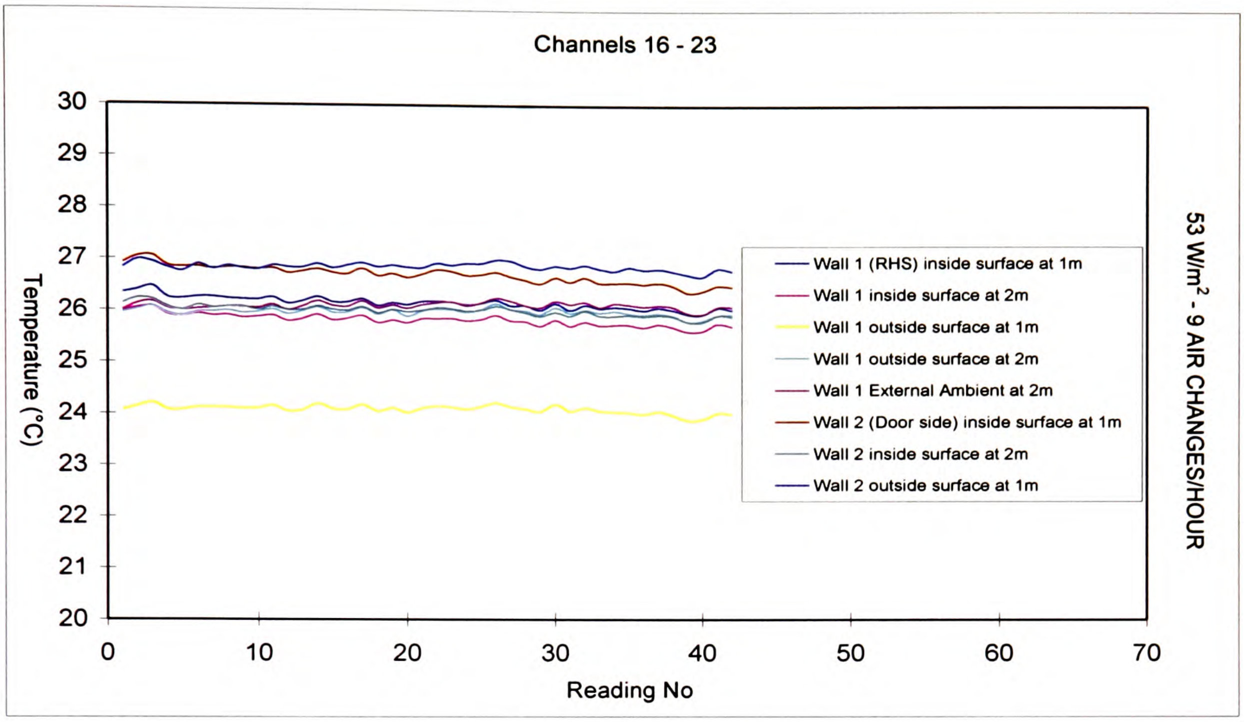
Experiment 1 - 53 W/m^2 with 9 air changes per hour

Real time heat loss calculations highlighted in green

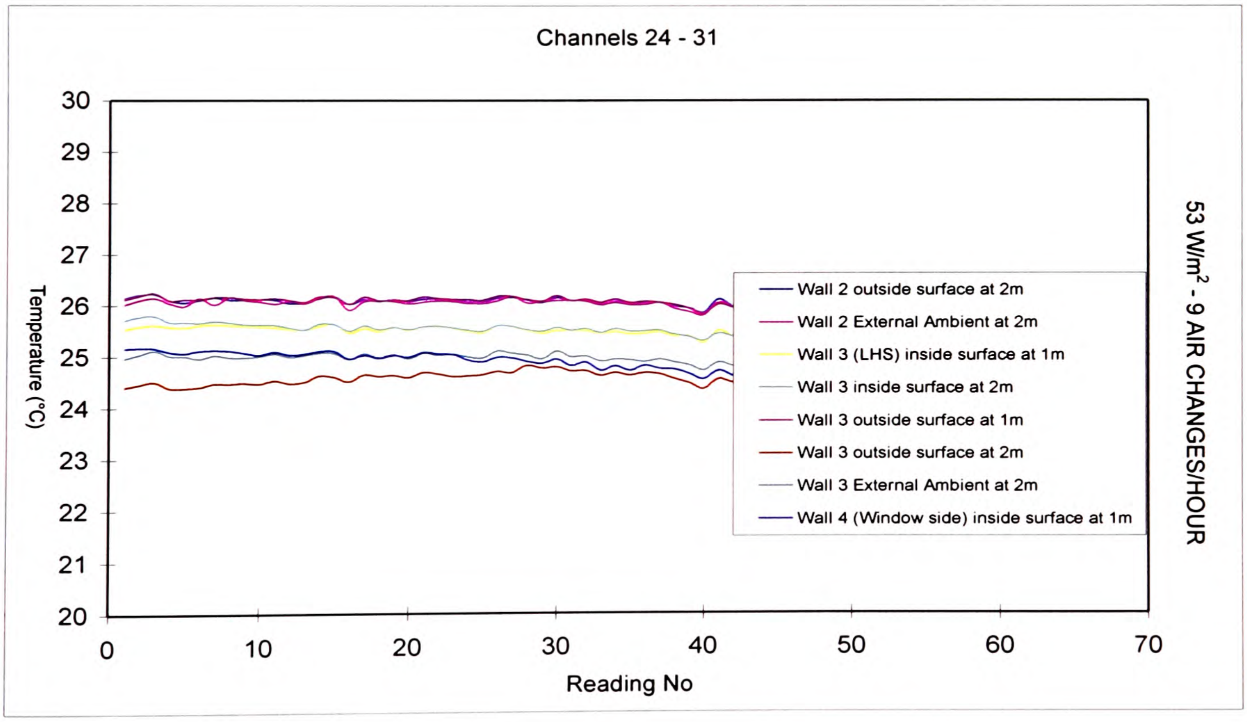
Channel	Location	Temp (°C)		A Positive figure indicates flux into the facility			
CH0	Air Supply 1 - LHS	20.17			3		
CH1	Air Supply 2 - RHS	20.51					
CH2	Air Supply Andrew Geens	18.30	Fluxes	Area	Δ T	U-value	Flux
CH3	Extract 1 - Near window	25.94		(m²)	(°C)	(W/m2K)	(W)
CH4	Extract 2 - Near door	26.00					
CH5	Globe 1 - Pole 1	22.84	Floor 1	5.0625	-2.12	0.715	-7.6847662
CH6	Globe 2 - Pole 1	24.28	Floor 2	5.0625	-1.86	0.715	-6.740961
CH7	Globe 1 - Pole 2	22.99	Floor 3	5.0625	-2.05	0.715	-7.405513
CH8	Globe 2 - Pole 2	23.92	Floor 4	5.0625	-2.11	0.715	-7.6529526
CH9	Ceiling 1 - LHS near window	24.50	Roof	20.25	0.35	1.21	8.4586267
CH10	Ceiling 2 - RHS near door	25.59	Wall 1 @ 2.9m	1.8	-2.03	0.717	-2.6152295
CH11	Ceiling 3 - LHS near door	25.26	Wall 1 @ 2m	12.85	0.23	0.717	2.1054173
CH12	On Floor 1 - LHS near window	22.87	Wall 1 average	13.95	-0.06	0.717	-0.6463303
CH13	On Floor 2 - RHS near door	22.44	Wall 2 @ 2.9m	1.8	0.30	0.717	0.3856676
CH14	On Floor 3 - LHS near door	22.50	Wall 2 @ 2m	12.85	0.05	0.717	0.4498755
CH15	On Floor 4 - RHS near window	22.99	Wall 2 average	13.95	0.08	0.717	0.8134561
CH16 - Ch0	Wall 1 (RHS) inside surface at 2.9m	26.03	Wall 3 @ 2.9	1.8	0.57	0.717	0.7373057
CH17 - Ch1	Wall 1 inside surface at 2m	25.71	Wall 3 @ 2m	12.85	-0.90	0.717	-8.259714
CH18 - Ch2	Wall 1 outside surface at 2.9m	24.00	Wall 3 average	13.95	-0.71	0.717	-7.0582555
CH19 - Ch3	Wall 1 outside surface at 2m	25.94	Wall 4 @ 1m	4.05	1.12	0.402	1.8204829
CH20 - Ch4	Wall 1 External Ambient at 2m	26.09	Wall 4 @ 2m	5.148	0.04	8.54	1.9320082
CH21 - Ch5	Wall 2 (Door side) inside surface at 2.9m	26.48	Wall 4 @ 2.5 m	4.752	0.52	0.402	0.9905971
CH22 - Ch6	Wall 2 inside surface at 2m	25.90	Wall 4 average	13.95	0.52	3.66	26.421418
CH23 - Ch7	Wall 2 outside surface at 2.9m	26.78	Beam 1		0.48	0	0
CH24 - Ch8	Wall 2 outside surface at 2m	25.95	Beam 2		0.66	0	0
CH25 - Ch9	Wall 2 External Ambient at 2m	25.95	Beam 3		8.29	0	0
CH26 - Ch10	Wall 3 (LHS) inside surface at 2.9m	25.37	Air		6.89		
CH27 - Ch11	Wall 3 inside surface at 2m	25.37					
CH28 - Ch12	Wall 3 outside surface at 2.9m	25.94					
CH29 - Ch13	Wall 3 outside surface at 2m	24.47					
CH30 - Ch14	Wall 3 External Ambient at 2m	24.80					
CH31 - Ch15	Wall 4 (Window side) inside surface at 1m	24.60					
CH32 - Ch0	Wall 4 inside surface at 2m (glass)	25.94					
CH33 - Ch1	Wall 4 inside surface at 2.5m	25.72					
CH34 - Ch2	Wall 4 outside surface at 1m	25.94					
CH35 - Ch3	Wall 4 outside surface at 2m (glass)	25.98					
CH36 - Ch4	Wall 4 outside surface at 2.5m	26.24					
CH37 - Ch5	Wall 4 External Ambient at 1m	26.15		Heat load			1150
CH38 - Ch6	Wall 4 External Ambient at 2m	26.11					
CH39 - Ch7	Roof Ambient 1	26.58		Cooling due to air system			1134.934
CH40 - Ch8	Under Floor 1 - LHS near window	20.75					
CH41 - Ch9	Under Floor 2 - RHS near door	20.57		Cooling due to water system			0
CH42 - Ch10	Under Floor 3 - LHS near door	20.46					
CH43 - Ch11	Under Floor 4 - RHS near window	20.88		Overall heat flux from facility			-1.4952773
CH44 - Ch12	Ceiling 4 - RHS near window	25.49					
CH45 - Ch13	Under Roof 1 - Near window	25.45		Energy Balance			13.570741
CH46 - Ch14	Under Roof 2 - Near door	26.96					
CH47 - Ch15	Roof Ambient 2	26.52					
CH48 - Ch0	Column 1 at 0.01 m	21.28		Av Column temp (°C)			
CH49 - Ch1	Column 1 at 0.1 m	21.85		21.542969	0.01		
CH50 - Ch2	Column 1 at 0.6 m	22.46		21.375488	0.1		
CH51 - Ch3	Column 1 at 1.1 m	23.89		22.157715	0.6		
CH52 - Ch4	Column 1 at 1.7 m	25.43		23.558594	1.1		
CH53 - Ch5	Column 1 at 2.1 m	25.74		25.23877	1.7		
CH54 - Ch6	Column 1 at 2.6 m	25.75		25.519531	2.1		
CH55 - Ch7	Column 1 at 2.69 m	25.73		25.625488	2.6		
CH56 - Ch8	Column 2 at 0.01 m	21.81		25.596191	2.69		
CH57 - Ch9	Column 2 at 0.1 m	20.90					
CH58 - Ch10	Column 2 at 0.6 m	21.86					
CH59 - Ch11	Column 2 at 1.1 m	23.22		Air flow rate	0.137	m³/s	
CH60 - Ch12	Column 2 at 1.7 m	25.04		Water flow r	0.00E+00	m³/s	
CH61 - Ch13	Column 2 at 2.1 m	25.30		Air Cp	1010	J/kgK	
CH62 - Ch14	Column 2 at 2.6 m	25.50		Water Cp	4180	J/kgK	
CH63 - Ch15	Column 2 at 2.69 m	25.46		Air density	1.19	kg/m³	
CH64 - Ch0 (PRT)	Beam 1 Supply	27.10		Water Densi	1000	kg/m³	
CH65 - Ch1 (PRT)	Beam 2 Supply	27.12					
CH66 - Ch2 (PRT)	Beam 3 Supply	19.08					
CH67 - Ch3 (PRT)	Beam 1 Return	27.58					
CH68 - Ch4 (PRT)	Beam 2 Return	27.78					
CH69 - Ch5 (PRT)	Beam 3 Return	27.37					


Channels 0 - 7
30
28
26
24
22
20
18
Temperature (°C)
0
10
20
30
40
50
60
70
Reading No
Air Supply 1 - LHS
Air Supply 2 - RHS
Air Supply 3 - Control Point
Extract 1 - Near window
Extract 2 - Near door
Globe 1 - Pole 1
Globe 2 - Pole 1
Globe 1 - Pole 2
53 W/m2 - 9 AIR CHANGES/HOUR

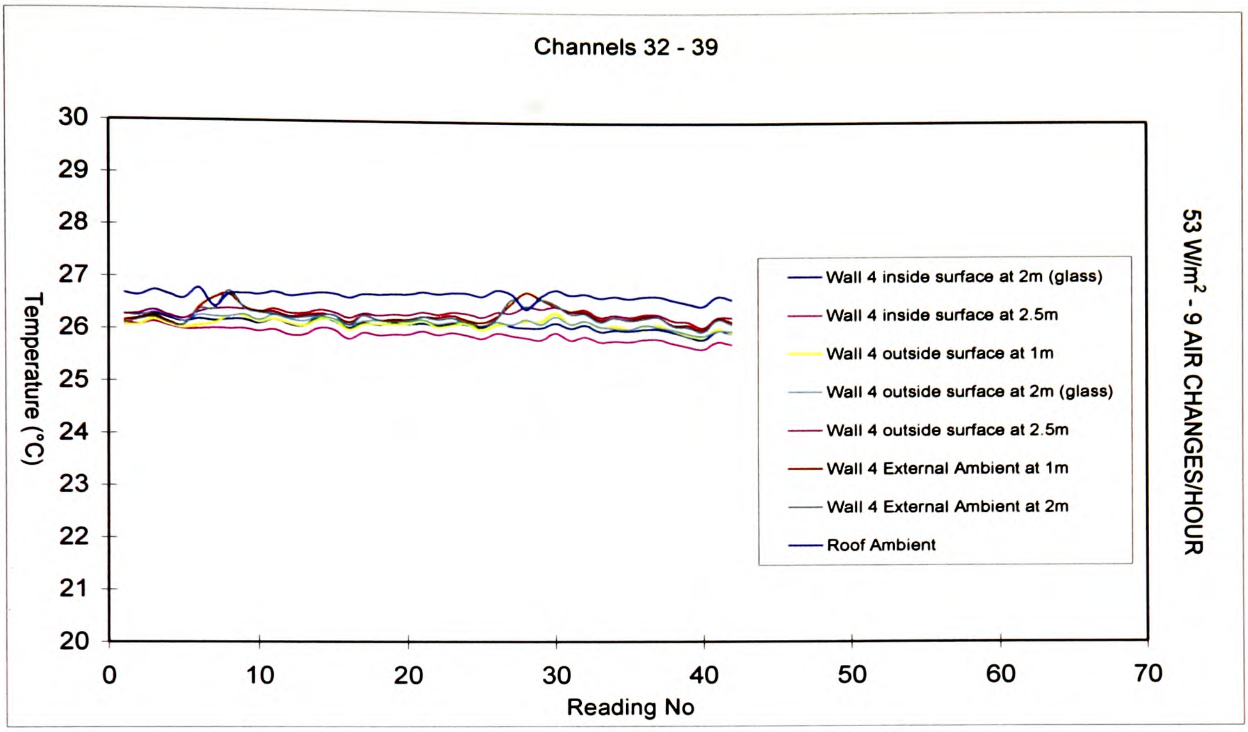

Channels 8 - 15
30
29
28
27
26
25
24
23
22
21
20
Temperature (°C)
0
10
20
30
40
50
60
70
Reading No
Globe 2 - Pole 2
Ceiling 1 - LHS near window
Ceiling 2 - RHS near door
Ceiling 3 - LHS near door
On Floor 1 - LHS near window
On Floor 2 - RHS near door
On Floor 3 - LHS near door
On Floor 4 - RHS near window
53 W/m2 - 9 AIR CHANGES/HOUR

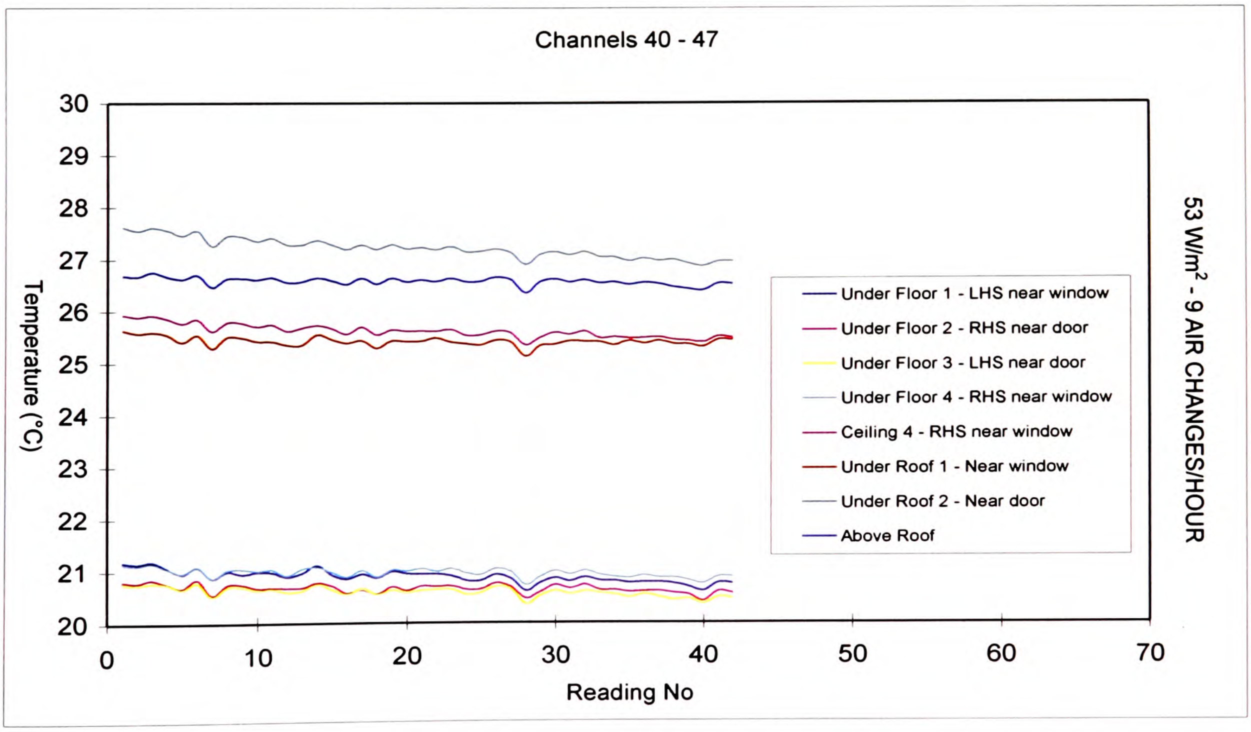


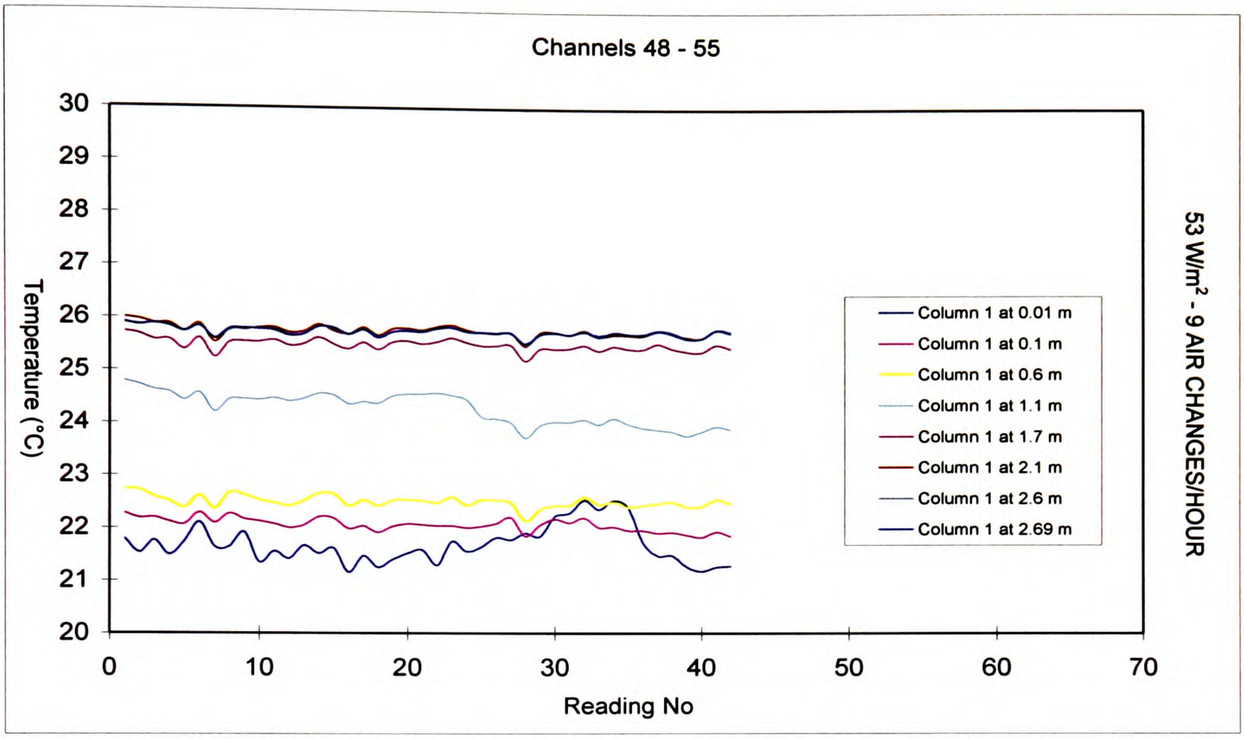
Channels 16 - 23
Temperature (°C)
Reading No
53 W/m2 - 9 AIR CHANGES/HOUR
Wall 1 (RHS) inside surface at 1m
Wall 1 inside surface at 2m
Wall 1 outside surface at 1m
Wall 1 outside surface at 2m
Wall 1 External Ambient at 2m
Wall 2 (Door side) inside surface at 1m
Wall 2 inside surface at 2m
Wall 2 outside surface at 1m



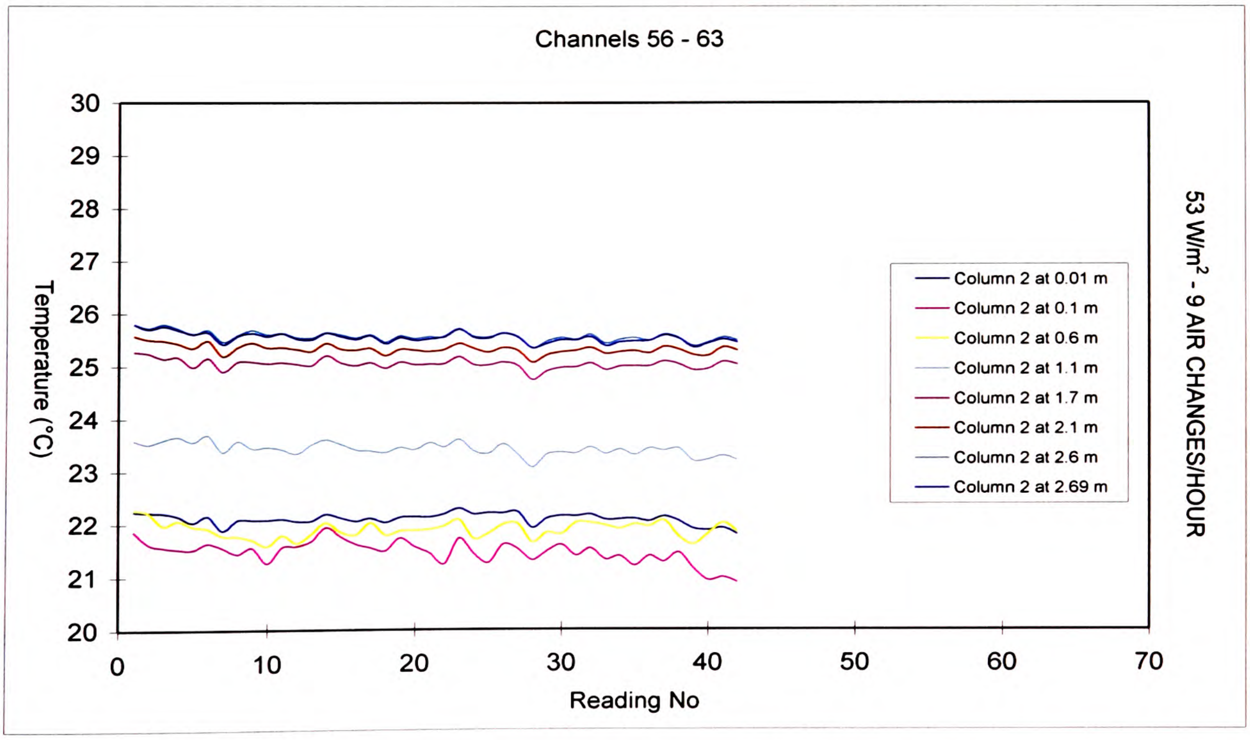
Channels 24 - 31
Temperature (°C)
Reading No
53 W/m2 - 9 AIR CHANGES/HOUR
Wall 2 outside surface at 2m
Wall 2 External Ambient at 2m
Wall 3 (LHS) inside surface at 1m
Wall 3 inside surface at 2m
Wall 3 outside surface at 1m
Wall 3 outside surface at 2m
Wall 3 External Ambient at 2m
Wall 4 (Window side) inside surface at 1m


Channels 32 - 39
Temperature (°C)
Reading No
53 W/m2 - 9 AIR CHANGES/HOUR
Wall 4 inside surface at 2m (glass)
Wall 4 inside surface at 2.5m
Wall 4 outside surface at 1m
Wall 4 outside surface at 2m (glass)
Wall 4 outside surface at 2.5m
Wall 4 External Ambient at 1m
Wall 4 External Ambient at 2m
Roof Ambient

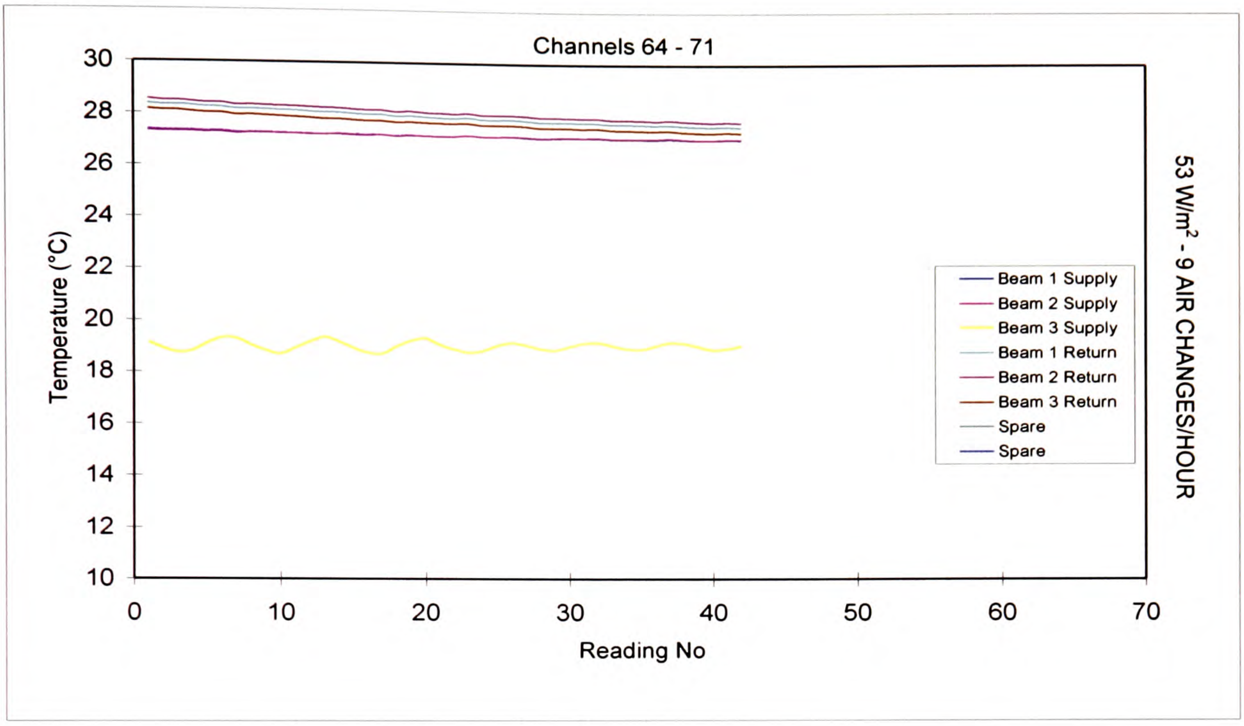

Channels 40 - 47
Temperature (°C)
Reading No
53 W/m2 - 9 AIR CHANGES/HOUR
Under Floor 1 - LHS near window
Under Floor 2 - RHS near door
Under Floor 3 - LHS near door
Under Floor 4 - RHS near window
Ceiling 4 - RHS near window
Under Roof 1 - Near window
Under Roof 2 - Near door
Above Roof



Channels 48 - 55
Temperature (°C)
30
29
28
27
26
25
24
23
22
21
20
0
10
20
30
40
50
60
70
Reading No
Column 1 at 0.01 m
Column 1 at 0.1 m
Column 1 at 0.6 m
Column 1 at 1.1 m
Column 1 at 1.7 m
Column 1 at 2.1 m
Column 1 at 2.6 m
Column 1 at 2.69 m
53 W/m2 - 9 AIR CHANGES/HOUR



Channels 56 - 63
Temperature (°C)
30
29
28
27
26
25
24
23
22
21
20
0
10
20
30
40
50
60
70
Reading No
Column 2 at 0.01 m
Column 2 at 0.1 m
Column 2 at 0.6 m
Column 2 at 1.1 m
Column 2 at 1.7 m
Column 2 at 2.1 m
Column 2 at 2.6 m
Column 2 at 2.69 m
53 W/m2 - 9 AIR CHANGES/HOUR


Channels 64 - 71
30
28
26
24
22
20
18
16
14
12
10
Temperature (°C)
0
10
20
30
40
50
60
70
Reading No
Beam 1 Supply
Beam 2 Supply
Beam 3 Supply
Beam 1 Return
Beam 2 Return
Beam 3 Return
Spare
Spare
53 W/m2 - 9 AIR CHANGES/HOUR

Summary sheet for Room Thermal Comfort Data

Experiment 4 - 53 W/m^2 with 3.5 air changes per hour plus chilled panels

Height	Av.Vel	Max.Vel	Min.Vel	Av.Temp	Max.Temp	Min.Temp	Av.PPD	Max.PPD	Min.PPD	Av.PMV	Max.PMV	Min.PMV	
0.1	0.054	0.082886	0.030673	21.3	22.6	20	12.51	19.92	7.71	-0.58	-0.361	-0.841	
0.6	0.053	0.109411	0.03697	22.9	23.2	22.6	7.28	8.33	5.78	-0.33	-0.194	-0.4	
1.1	0.061	0.102765	0.035739	23.8	24.7	23.3	5.26	5.85	5	-0.08	0.109	-0.203	
1.7	0.05	0.074102	0.038301	23.9	24.2	23.5	5.15	5.39	5	-0.06	0.126	-0.137	
2.1	0.058	0.083094	0.041496	23.8	24.2	23.5	5.21	5.58	5	-0.08	0.093	-0.167	
2.6	0.105	0.173221	0.057198	23.8	24.4	23.2	5.51	7.21	5.01	-0.14	-0.02	-0.326	
0.1	0.069	0.11417	0.043962	20.5	22	18.7	13.82	25.45	7.9	-0.63	-0.373	-0.984	
0.6	0.04	0.066415	0.029688	22.6	22.9	22.2	7.61	8.97	6.04	-0.35	-0.224	-0.436	
1.1	0.061	0.102963	0.03621	23.8	24.3	23.2	5.42	6.26	5.01	-0.1	0.152	-0.246	
1.7	0.06	0.157046	0.033547	23.9	24.3	23.1	5.32	6.68	5	-0.09	0.103	-0.284	
2.1	0.066	0.128374	0.041092	23.8	24.2	22.9	5.32	6.41	5	-0.1	0.032	-0.261	
2.6	0.093	0.130344	0.047221	24.1	25.1	23.3	5.45	7.49	5	-0.08	0.157	-0.346	
Occ.Zone	0.056333	0.11417	0.029688	22.48333	24.7	18.7	8.65	25.45	5	-0.345	25.45	-0.984	
				AV TEMP			AV VEL			AV PPD			AV PMV
ADPI =	32.92308	21.3	20.5	20.9	0.054	0.069	0.0615	12.51	13.82	13.165	-0.58	-0.63	-0.605
		22.9	22.6	22.75	0.053	0.04	0.0465	7.28	7.61	7.445	-0.33	-0.35	-0.34
Clo value:	0.6	23.8	23.8	23.8	0.061	0.061	0.061	5.26	5.42	5.34	-0.08	-0.1	-0.09
Ext.Work:	0	23.9	23.9	23.9	0.05	0.06	0.055	5.15	5.32	5.235	-0.06	-0.09	-0.075
Humidity:	50	23.8	23.8	23.8	0.058	0.066	0.062	5.21	5.32	5.265	-0.08	-0.1	-0.09
Met.Rate:	1.2	23.8	24.1	23.95	0.105	0.093	0.099	5.51	5.45	5.48	-0.14	-0.08	-0.11

Detailed Thermal Comfort Data

Experiment 4 - 53 W/m^2 with 3.5 air changes per hour plus chilled panels

			Test Start Date: 20\8\1996														
			Measurement Time: 180 secs.														
X-Pos (m)	Y-Pos (m)	Height (m)	Time	Rel.Time	Vel	Turb'ce	Temp	Reading	Globe temp	Corr'd Vel	Corr'd Temp	Shifted Temp.	Shifted Globe temp	Rad Temp	DR	PPD	PMV
0.75	0.25	0.1	14:030	00:49:33	0.058	34.3	21.2	9		0.06	20.7	20.7		22.8	2.9	14.9	-0.69
1.75	0.25	0.1	14:035	00:55:28	0.038	41.5	22.4	10		0.04	21.9	21.9		22.7	0	10.2	-0.5
2.75	0.25	0.1	15:019	01:38:33	0.053	21.9	22.4	17		0.055	21.9	21.9		23.1	1.6	9.08	-0.44
3.75	0.25	0.1	13:040	00:00:00	0.048	33.6	21.5	1		0.05	21	21		23	0	12.8	-0.61
0.75	0.75	0.1	14:024	00:43:35	0.056	24.3	21.6	8		0.058	21.1	21.1		22.6	2.3	13.6	-0.64
1.75	0.75	0.1	14:042	01:01:31	0.034	44.7	22.4	11		0.036	21.9	21.9		22.8	0	9.79	-0.48
2.75	0.75	0.1	15:012	01:32:24	0.053	28.5	22.3	16		0.055	21.8	21.8		23.9	1.7	7.71	-0.36
3.75	0.75	0.1	13:046	00:06:16	0.055	22.3	21.8	2		0.057	21.3	21.3		22.8	2.1	12.1	-0.58
0.75	1.25	0.1	14:018	00:37:34	0.059	25.1	21.6	7		0.061	21.1	21.1		22.8	2.9	13	-0.62
1.75	1.25	0.1	14:048	01:07:34	0.043	25.7	22.4	12		0.045	21.9	21.9		22.6	0	10.3	-0.5
2.25	1.25	0.1	15:045	02:05:05	0.058	26.3	21.9	21		0.06	21.4	21.4		22.6	2.6	12.4	-0.59
3.75	1.25	0.1	13:053	00:12:35	0.066	18.3	21	3		0.067	20.6	20.6		22.5	3.9	16.4	-0.74
0.75	1.75	0.1	14:012	00:31:37	0.079	19.8	20.4	6		0.08	20	20		22.5	5.9	19.9	-0.84
1.75	1.75	0.1	14:054	01:13:33	0.043	34.8	22.4	13		0.045	21.9	21.9		22.5	0	10.5	-0.51
2.75	1.75	0.1	15:06:	01:25:43	0.041	47.7	21.7	15		0.043	21.2	21.2		22.7	0	13	-0.62
3.75	1.75	0.1	14:00:	00:19:49	0.076	21	20.7	4		0.077	20.3	20.3		22.4	5.5	18.4	-0.8
0.75	2.25	0.1	14:06:	00:25:43	0.042	45	21.4	5		0.044	20.9	20.9		22.5	0	14.9	-0.69
1.75	2.25	0.1	14:059	01:19:30	0.028	36.9	22.2	15		0.031	21.7	21.7		22.7	0	10.9	-0.53
2.25	2.25	0.1	15:037	01:57:19	0.041	28	22.4	20		0.043	21.9	21.9		22.6	0	10.5	-0.51
2.75	2.25	0.1	14:059	01:19:30	0.028	36.9	22.2	15		0.031	21.7	21.7		22.7	0	10.9	-0.53
3.75	2.25	0.1	14:06:	00:25:43	0.042	45	21.4	5		0.044	20.9	20.9		22.5	0	14.9	-0.69
0.75	2.75	0.1	14:00:	00:19:49	0.076	21	20.7	4		0.077	20.3	20.3		22.4	5.5	18.4	-0.8
1.75	2.75	0.1	15:06:	01:25:43	0.041	47.7	21.7	15		0.043	21.2	21.2		22.7	0	13	-0.62
2.75	2.75	0.1	14:054	01:13:33	0.043	34.8	22.4	13		0.045	21.9	21.9		22.5	0	10.5	-0.51
3.75	2.75	0.1	14:012	00:31:37	0.079	19.8	20.4	6		0.08	20	20		22.5	5.9	19.9	-0.84
0.75	3.25	0.1	13:053	00:12:35	0.066	18.3	21	3		0.067	20.6	20.6		22.5	3.9	16.4	-0.74
2.25	3.25	0.1	15:031	01:50:37	0.067	35.3	23.1	19		0.068	22.6	22.6		22.8	3.9	7.71	-0.36
2.75	3.25	0.1	14:048	01:07:34	0.043	25.7	22.4	12		0.045	21.9	21.9		22.6	0	10.3	-0.5
3.75	3.25	0.1	14:018	00:37:34	0.059	25.1	21.6	7		0.061	21.1	21.1		22.8	2.9	13	-0.62
0.75	3.75	0.1	13:046	00:06:16	0.055	22.3	21.8	2		0.057	21.3	21.3		22.8	2.1	12.1	-0.58
1.75	3.75	0.1	15:012	01:32:24	0.053	28.5	22.3	16		0.055	21.8	21.8		23.9	1.7	7.71	-0.36
2.75	3.75	0.1	14:042	01:01:31	0.034	44.7	22.4	11		0.036	21.9	21.9		22.8	0	9.79	-0.48
3.75	3.75	0.1	14:024	00:43:35	0.056	24.3	21.6	8		0.058	21.1	21.1		22.6	2.3	13.6	-0.64
0.75	4.25	0.1	13:040	00:00:00	0.048	33.6	21.5	1		0.05	21	21		23	0	12.8	-0.61
1.75	4.25	0.1	15:019	01:38:33	0.053	21.9	22.4	17		0.055	21.9	21.9		23.1	1.6	9.08	-0.44

2.25	4.25	0.1	15:025	01:44:33	0.082	20.8	22.9	18		0.083	22.4	22.4		22.7	5.3	8.45	-0.41
2.75	4.25	0.1	14:035	00:55:28	0.038	41.5	22.4	10		0.04	21.9	21.9		22.7	0	10.2	-0.5
3.75	4.25	0.1	14:030	00:49:33	0.058	34.3	21.2	9		0.06	20.7	20.7		22.8	2.9	14.9	-0.69
49.25	49.25	0.1	15:051	02:11:24	0.058	39.7	21.6	22		0.06	21.1	21.1		22.5	2.9	13.9	-0.65
0.75	0.25	0.6	14:030	00:49:33	0.104	25.6	23.2	9	22.79	0.109	22.8	22.8	22.79	22.8	8.1	8.12	-0.39
1.75	0.25	0.6	14:035	00:55:28	0.041	34.1	23.3	10	22.76	0.045	22.9	22.9	22.76	22.7	0	7.31	-0.33
2.75	0.25	0.6	15:019	01:38:33	0.04	18.6	23.3	17	23.03	0.044	22.9	22.9	23.03	23.1	0	6.59	-0.28
3.75	0.25	0.6	13:040	00:00:00	0.06	47.5	23	1	22.82	0.065	22.6	22.6	22.82	23	3.5	7.42	-0.34
0.75	0.75	0.6	14:024	00:43:35	0.101	28.1	23.2	8	22.7	0.106	22.8	22.8	22.7	22.6	8	8.33	-0.4
1.75	0.75	0.6	14:042	01:01:31	0.042	20.5	23.3	11	22.85	0.046	22.9	22.9	22.85	22.8	0	7.05	-0.31
2.75	0.75	0.6	15:012	01:32:24	0.045	21.1	23.2	16	23.45	0.049	22.8	22.8	23.45	23.9	0	5.78	-0.19
3.75	0.75	0.6	13:046	00:06:16	0.042	28.2	23.5	2	22.92	0.046	23.1	23.1	22.92	22.8	0	6.68	-0.28
0.75	1.25	0.6	14:018	00:37:34	0.059	46.8	23	7	22.7	0.063	22.6	22.6	22.7	22.8	3.4	7.83	-0.37
1.75	1.25	0.6	14:048	01:07:34	0.04	14.9	23.4	12	22.77	0.044	23	23	22.77	22.6	0	7.16	-0.32
2.25	1.25	0.6	15:045	02:05:05	0.042	15.1	23.2	21	22.66	0.046	22.8	22.8	22.66	22.6	0	7.74	-0.36
3.75	1.25	0.6	13:053	00:12:35	0.04	18	23.6	3	22.78	0.044	23.2	23.2	22.78	22.5	0	6.93	-0.31
0.75	1.75	0.6	14:012	00:31:37	0.04	30.9	23.3	6	22.65	0.044	22.9	22.9	22.65	22.5	0	7.64	-0.36
1.75	1.75	0.6	14:054	01:13:33	0.042	14.5	23.3	13	22.68	0.046	22.9	22.9	22.68	22.5	0	7.55	-0.35
2.75	1.75	0.6	15:06:	01:25:43	0.041	9.7	23.3	15	22.75	0.045	22.9	22.9	22.75	22.7	0	7.33	-0.34
3.75	1.75	0.6	14:00:	00:19:49	0.038	21.6	23.6	4	22.72	0.042	23.2	23.2	22.72	22.4	0	7.08	-0.32
0.75	2.25	0.6	14:06:	00:25:43	0.04	16.6	23.6	5	22.78	0.044	23.2	23.2	22.78	22.5	0	6.93	-0.31
1.75	2.25	0.6	14:059	01:19:30	0.038	19.9	23.2	15	22.76	0.042	22.8	22.8	22.76	22.7	0	7.43	-0.34
2.25	2.25	0.6	15:037	01:57:19	0.039	18.6	23.2	20	22.65	0.043	22.8	22.8	22.65	22.6	0	7.76	-0.36
2.75	2.25	0.6	14:059	01:19:30	0.038	19.9	23.2	15	22.76	0.042	22.8	22.8	22.76	22.7	0	7.43	-0.34
3.75	2.25	0.6	14:06:	00:25:43	0.04	16.6	23.6	5	22.78	0.044	23.2	23.2	22.78	22.5	0	6.93	-0.31
0.75	2.75	0.6	14:00:	00:19:49	0.038	21.6	23.6	4	22.72	0.042	23.2	23.2	22.72	22.4	0	7.08	-0.32
1.75	2.75	0.6	15:06:	01:25:43	0.041	9.7	23.3	15	22.75	0.045	22.9	22.9	22.75	22.7	0	7.33	-0.34
2.75	2.75	0.6	14:054	01:13:33	0.042	14.5	23.3	13	22.68	0.046	22.9	22.9	22.68	22.5	0	7.55	-0.35
3.75	2.75	0.6	14:012	00:31:37	0.04	30.9	23.3	6	22.65	0.044	22.9	22.9	22.65	22.5	0	7.64	-0.36
0.75	3.25	0.6	13:053	00:12:35	0.04	18	23.6	3	22.78	0.044	23.2	23.2	22.78	22.5	0	6.93	-0.31
2.25	3.25	0.6	15:031	01:50:37	0.033	26.1	23.1	19	22.79	0.037	22.7	22.7	22.79	22.8	0	7.48	-0.35
2.75	3.25	0.6	14:048	01:07:34	0.04	14.9	23.4	12	22.77	0.044	23	23	22.77	22.6	0	7.16	-0.32
3.75	3.25	0.6	14:018	00:37:34	0.059	46.8	23	7	22.7	0.063	22.6	22.6	22.7	22.8	3.4	7.83	-0.37
0.75	3.75	0.6	13:046	00:06:16	0.042	28.2	23.5	2	22.92	0.046	23.1	23.1	22.92	22.8	0	6.68	-0.28
1.75	3.75	0.6	15:012	01:32:24	0.045	21.1	23.2	16	23.45	0.049	22.8	22.8	23.45	23.9	0	5.78	-0.19
2.75	3.75	0.6	14:042	01:01:31	0.042	20.5	23.3	11	22.85	0.046	22.9	22.9	22.85	22.8	0	7.05	-0.31
3.75	3.75	0.6	14:024	00:43:35	0.101	28.1	23.2	8	22.7	0.106	22.8	22.8	22.7	22.6	8	8.33	-0.4
0.75	4.25	0.6	13:040	00:00:00	0.06	47.5	23	1	22.82	0.065	22.6	22.6	22.82	23	3.5	7.42	-0.34
1.75	4.25	0.6	15:019	01:38:33	0.04	18.6	23.3	17	23.03	0.044	22.9	22.9	23.03	23.1	0	6.59	-0.28
2.25	4.25	0.6	15:025	01:44:33	0.036	26.4	23.4	18	22.84	0.04	23	23	22.84	22.7	0	6.97	-0.31
2.75	4.25	0.6	14:035	00:55:28	0.041	34.1	23.3	10	22.76	0.045	22.9	22.9	22.76	22.7	0	7.31	-0.33
3.75	4.25	0.6	14:030	00:49:33	0.104	25.6	23.2	9	22.79	0.109	22.8	22.8	22.79	22.8	8.1	8.12	-0.39
49.25	49.25	0.6	15:051	02:11:24	0.039	16.9	23.2	22	22.63	0.043	22.8	22.8	22.63	22.5	0	7.82	-0.37
0.75	0.25	1.1	14:030	00:49:33	0.062	37	23.9	9	23.39	0.053	23.5	23.5	23.39	23.3	1.1	5.5	-0.16
1.75	0.25	1.1	14:035	00:55:28	0.109	13.8	23.8	10	23.37	0.103	23.4	23.4	23.37	23.3	6.3	5.85	-0.2
2.75	0.25	1.1	15:019	01:38:33	0.047	20.1	24.5	17	24.04	0.037	24.1	24.1	24.04	24	0	5.02	0.03
3.75	0.25	1.1	13:040	00:00:00	0.086	25.9	23.7	1	23.69	0.078	23.3	23.3	23.69	24	4.6	5.19	-0.1
0.75	0.75	1.1	14:024	00:43:35	0.064	42.1	24.3	8	23.43	0.055	23.9	23.9	23.43	23.1	1.5	5.29	-0.12
1.75	0.75	1.1	14:042	01:01:31	0.048	32.6	24.4	11	23.55	0.038	24	24	23.55	23.3	0	5.13	-0.08
2.75	0.75	1.1	15:012	01:32:24	0.054	23.5	24.5	16	24.42	0.044	24.1	24.1	24.42	24.6	0	5.25	0.11
3.75	0.75	1.1	13:046	00:06:16	0.081	26.1	23.9	2	23.64	0.073	23.5	23.5	23.64	23.8	3.9	5.2	-0.1
0.75	1.25	1.1	14:018	00:37:34	0.076	36.9	23.9	7	23.42	0.068	23.5	23.5	23.42	23.4	3.5	5.47	-0.15
1.75	1.25	1.1	14:048	01:07:34	0.06	41.6	24.3	12	23.5	0.051	23.9	23.9	23.5	23.2	0.4	5.21	-0.1
2.25	1.25	1.1	15:045	02:05:05	0.097	19.3	24.3	21	23.73	0.09	23.9	23.9	23.73	23.6	5.2	5.07	-0.06
3.75	1.25	1.1	13:053	00:12:35	0.064	34.7	23.9	3	23.55	0.055	23.5	23.5	23.55	23.6	1.5	5.3	-0.12
0.75	1.75	1.1	14:012	00:31:37	0.109	18.8	23.7	6	23.4	0.103	23.3	23.3	23.4	23.5	6.7	5.8	-0.2
1.75	1.75	1.1	14:054	01:13:33	0.075	31.3	24.3	13	23.45	0.067	23.9	23.9	23.45	23.1	3.1	5.29	-0.12
2.75	1.75	1.1	15:06:	01:25:43	0.05	20.4	24.5	15	23.8	0.04	24.1	24.1	23.8	23.6	0	5.01	-0.02
3.75	1.75	1.1	14:00:	00:19:49	0.082	25.9	24.3	4	23.59	0.074	23.9	23.9	23.59	23.3	3.9	5.16	-0.09
0.75	2.25	1.1	14:06:	00:25:43	0.066	30.1	24.4	5	23.51	0.057	24	24	23.51	23.1	1.7	5.19	-0.1
1.75	2.25	1.1	14:059	01:19:30	0.067	27.9	24.4	15	23.65	0.058	24	24	23.65	23.4	1.9	5.09	-0.07
2.25	2.25	1.1	15:037	01:57:19	0.049	22.3	24.9	20	23.7	0.039	24.5	24.5	23.7	23.2	0	5	-0.01
2.75	2.25	1.1	14:059	01:19:30	0.067	27.9	24.4	15	23.65	0.058	24	24	23.65	23.4	1.9	5.09	-0.07
3.75	2.25	1.1	14:06:	00:25:43	0.066	30.1	24.4	5	23.51	0.057	24	24	23.51	23.1	1.7	5.19	-0.1
0.75	2.75	1.1	14:00:	00:19:49	0.082	25.9	24.3	4	23.59	0.074	23.9	23.9	23.59	23.3	3.9	5.16	-0.09
1.75	2.75	1.1	15:06:	01:25:43	0.05	20.4	24.5	15	23.8	0.04	24.1	24.1	23.8	23.6	0	5.01	-0.02
2.75	2.75	1.1	14:054	01:13:33	0.075	31.3	24.3	13	23.45	0.067	23.9	23.9	23.45	23.1	3.1	5.29	-0.12
3.75	2.75	1.1	14:012	00:31:37	0.109	18.8	23.7	6	23.4	0.103	23.3	23.3	23.4	23.5	6.7	5.8	-0.2
0.75	3.25	1.1	13:053	00:12:35	0.064	34.7	23.9	3	23.55	0.055	23.5	23.5	23.55	23.6	1.5	5.3	-0.12
2.25	3.25	1.1	15:031	01:50:37	0.054	24	25	19	23.8	0.044	24.6	24.6	23.8	23.3	0	5.01	0.02

2.75	3.25	1.1	14:048	01:07:34	0.06	41.6	24.3	12	23.5	0.051	23.9	23.9	23.5	23.2	0.4	5.21	-0.1
3.75	3.25	1.1	14:018	00:37:34	0.076	36.9	23.9	7	23.42	0.068	23.5	23.5	23.42	23.4	3.5	5.47	-0.15
0.75	3.75	1.1	13:046	00:06:16	0.081	26.1	23.9	2	23.64	0.073	23.5	23.5	23.64	23.8	3.9	5.2	-0.1
1.75	3.75	1.1	15:012	01:32:24	0.054	23.5	24.5	16	24.42	0.044	24.1	24.1	24.42	24.6	0	5.25	0.11
2.75	3.75	1.1	14:042	01:01:31	0.048	32.6	24.4	11	23.55	0.038	24	24	23.55	23.3	0	5.13	-0.08
3.75	3.75	1.1	14:024	00:43:35	0.064	42.1	24.3	8	23.43	0.055	23.9	23.9	23.43	23.1	1.5	5.29	-0.12
0.75	4.25	1.1	13:040	00:00:00	0.086	25.9	23.7	1	23.69	0.078	23.3	23.3	23.69	24	4.6	5.19	-0.1
1.75	4.25	1.1	15:019	01:38:33	0.047	20.1	24.5	17	24.04	0.037	24.1	24.1	24.04	24	0	5.02	0.03
2.25	4.25	1.1	15:025	01:44:33	0.046	31.1	25.1	18	23.78	0.036	24.7	24.7	23.78	23.2	0	5.02	0.03
2.75	4.25	1.1	14:035	00:55:28	0.109	13.8	23.8	10	23.37	0.103	23.4	23.4	23.37	23.3	6.3	5.85	-0.2
3.75	4.25	1.1	14:030	00:49:33	0.062	37	23.9	9	23.39	0.053	23.5	23.5	23.39	23.3	1.1	5.5	-0.16
49.25	49.25	1.1	15:051	02:11:24	0.092	25.4	24.2	22	23.75	0.085	23.8	23.8	23.75	23.7	5	5.07	-0.06
0.75	0.25	1.7	14:030	00:49:33	0.048	53.8	24.3	9		0.049	23.8	23.8		23.3	0	5.23	-0.11
1.75	0.25	1.7	14:035	00:55:28	0.056	28.9	24.5	10		0.057	24	24		23.3	1.7	5.1	-0.07
2.75	0.25	1.7	15:019	01:38:33	0.052	33.5	24.4	17		0.053	23.9	23.9		24	1	5	-0
3.75	0.25	1.7	13:040	00:00:00	0.049	40.3	24.3	1		0.05	23.8	23.8		24	0	5	-0.01
0.75	0.75	1.7	14:024	00:43:35	0.037	46.6	24.5	8		0.038	24	24		23.1	0	5.22	-0.1
1.75	0.75	1.7	14:042	01:01:31	0.046	45	24.5	11		0.047	24	24		23.3	0	5.13	-0.08
2.75	0.75	1.7	15:012	01:32:24	0.044	30.9	24.7	16		0.045	24.2	24.2		24.6	0	5.33	0.13
3.75	0.75	1.7	13:046	00:06:16	0.058	37.8	24.2	2		0.059	23.7	23.7		23.8	2.1	5.09	-0.07
0.75	1.25	1.7	14:018	00:37:34	0.044	42.4	24.5	7		0.045	24	24		23.4	0	5.1	-0.07
1.75	1.25	1.7	14:048	01:07:34	0.052	57	24.3	12		0.053	23.8	23.8		23.2	1.1	5.28	-0.12
2.25	1.25	1.7	15:045	02:05:05	0.043	38.1	24.7	21		0.044	24.2	24.2		23.6	0	5	-0.01
3.75	1.25	1.7	13:053	00:12:35	0.073	28.4	24	3		0.073	23.5	23.5		23.6	4	5.3	-0.12
0.75	1.75	1.7	14:012	00:31:37	0.045	33.6	24.7	6		0.046	24.2	24.2		23.5	0	5.01	-0.02
1.75	1.75	1.7	14:054	01:13:33	0.037	46.8	24.5	13		0.038	24	24		23.1	0	5.22	-0.1
2.75	1.75	1.7	15:06:	01:25:43	0.052	25.1	24.4	15		0.053	23.9	23.9		23.6	1	5.06	-0.05
3.75	1.75	1.7	14:00:	00:19:49	0.074	30.2	24.1	4		0.074	23.6	23.6		23.3	4.1	5.39	-0.14
0.75	2.25	1.7	14:06:	00:25:43	0.045	37	24.5	5		0.046	24	24		23.1	0	5.19	-0.1
1.75	2.25	1.7	14:059	01:19:30	0.038	42.9	24.7	15		0.039	24.2	24.2		23.6	0	5	-0
2.25	2.25	1.7	15:037	01:57:19	0.042	29.1	24.5	20		0.043	24	24		23.2	0	5.16	-0.09
2.75	2.25	1.7	14:059	01:19:30	0.038	42.9	24.7	15		0.039	24.2	24.2		23.6	0	5	-0
3.75	2.25	1.7	14:06:	00:25:43	0.045	37	24.5	5		0.046	24	24		23.1	0	5.19	-0.1
0.75	2.75	1.7	14:00:	00:19:49	0.074	30.2	24.1	4		0.074	23.6	23.6		23.3	4.1	5.39	-0.14
1.75	2.75	1.7	15:06:	01:25:43	0.052	25.1	24.4	15		0.053	23.9	23.9		23.6	1	5.06	-0.05
2.75	2.75	1.7	14:054	01:13:33	0.037	46.8	24.5	13		0.038	24	24		23.1	0	5.22	-0.1
3.75	2.75	1.7	14:012	00:31:37	0.045	33.6	24.7	6		0.046	24.2	24.2		23.5	0	5.01	-0.02
0.75	3.25	1.7	13:053	00:12:35	0.073	28.4	24	3		0.073	23.5	23.5		23.6	4	5.3	-0.12
2.25	3.25	1.7	15:031	01:50:37	0.037	36.5	24.4	19		0.038	23.9	23.9		23.3	0	5.19	-0.1
2.75	3.25	1.7	14:048	01:07:34	0.052	57	24.3	12		0.053	23.8	23.8		23.2	1.1	5.28	-0.12
3.75	3.25	1.7	14:018	00:37:34	0.044	42.4	24.5	7		0.045	24	24		23.4	0	5.1	-0.07
0.75	3.75	1.7	13:046	00:06:16	0.058	37.8	24.2	2		0.059	23.7	23.7		23.8	2.1	5.09	-0.07
1.75	3.75	1.7	15:012	01:32:24	0.044	30.9	24.7	16		0.045	24.2	24.2		24.6	0	5.33	0.13
2.75	3.75	1.7	14:042	01:01:31	0.046	45	24.5	11		0.047	24	24		23.3	0	5.13	-0.08
3.75	3.75	1.7	14:024	00:43:35	0.037	46.6	24.5	8		0.038	24	24		23.1	0	5.22	-0.1
0.75	4.25	1.7	13:040	00:00:00	0.049	40.3	24.3	1		0.05	23.8	23.8		24	0	5	-0.01
1.75	4.25	1.7	15:019	01:38:33	0.052	33.5	24.4	17		0.053	23.9	23.9		24	1	5	-0
2.25	4.25	1.7	15:025	01:44:33	0.058	39.2	24.3	18		0.059	23.8	23.8		23.2	2.1	5.28	-0.12
2.75	4.25	1.7	14:035	00:55:28	0.056	28.9	24.5	10		0.057	24	24		23.3	1.7	5.1	-0.07
3.75	4.25	1.7	14:030	00:49:33	0.048	53.8	24.3	9		0.049	23.8	23.8		23.3	0	5.23	-0.11
49.25	49.25	1.7	15:051	02:11:24	0.048	33.4	24.6	22		0.049	24.1	24.1		23.7	0	5	-0.01
0.75	0.25	2.1	14:030	00:49:33	0.068	42.6	23.8	9		0.069	23.5	23.5		23.3	3.8	5.5	-0.16
1.75	0.25	2.1	14:035	00:55:28	0.063	47.1	24	10		0.064	23.7	23.7		23.3	3.1	5.29	-0.12
2.75	0.25	2.1	15:019	01:38:33	0.061	46.5	24.4	17		0.062	24.1	24.1		24	2.7	5.02	0.03
3.75	0.25	2.1	13:040	00:00:00	0.068	39.3	24.1	1		0.069	23.8	23.8		24	3.6	5	-0.01
0.75	0.75	2.1	14:024	00:43:35	0.055	42.3	24	8		0.056	23.7	23.7		23.1	1.7	5.47	-0.15
1.75	0.75	2.1	14:042	01:01:31	0.058	27.7	24.3	11		0.059	24	24		23.3	2	5.13	-0.08
2.75	0.75	2.1	15:012	01:32:24	0.083	47.6	24.3	16		0.083	24	24		24.6	5.6	5.18	0.09
3.75	0.75	2.1	13:046	00:06:16	0.048	33	24.2	2		0.049	23.9	23.9		23.8	0	5.02	-0.03
0.75	1.25	2.1	14:018	00:37:34	0.045	66.8	24.2	7		0.046	23.9	23.9		23.4	0	5.15	-0.09
1.75	1.25	2.1	14:048	01:07:34	0.04	76.2	24.1	12		0.041	23.8	23.8		23.2	0	5.28	-0.12
2.25	1.25	2.1	15:045	02:05:05	0.052	38.1	24.3	21		0.053	24	24		23.6	1.1	5.03	-0.04
3.75	1.25	2.1	13:053	00:12:35	0.055	26.6	24.2	3		0.056	23.9	23.9		23.6	1.6	5.06	-0.05
0.75	1.75	2.1	14:012	00:31:37	0.054	32.6	24.5	6		0.055	24.2	24.2		23.5	1.4	5.01	-0.02
1.75	1.75	2.1	14:054	01:13:33	0.063	51	23.9	13		0.064	23.6	23.6		23.1	3.2	5.58	-0.17
2.75	1.75	2.1	15:06:	01:25:43	0.059	23.4	24.1	15		0.06	23.8	23.8		23.6	2.1	5.1	-0.07
3.75	1.75	2.1	14:00:	00:19:49	0.059	28.7	24	4		0.06	23.7	23.7		23.3	2.2	5.3	-0.12
0.75	2.25	2.1	14:06:	00:25:43	0.053	44.1	24.1	5		0.054	23.8	23.8		23.1	1.4	5.33	-0.13
1.75	2.25	2.1	14:059	01:19:30	0.05	57.4	24.1	15		0.051	23.8	23.8		23.6	0.7	5.1	-0.07
2.25	2.25	2.1	15:037	01:57:19	0.043	48.3	24.1	20		0.044	23.8	23.8		23.2	0	5.3	-0.12

2.75	2.25	2.1	14:059	01:19:30	0.05	57.4	24.1	15		0.051	23.8	23.8		23.6	0.7	5.1	-0.07
3.75	2.25	2.1	14:06:	00:25:43	0.053	44.1	24.1	5		0.054	23.8	23.8		23.1	1.4	5.33	-0.13
0.75	2.75	2.1	14:00:	00:19:49	0.059	28.7	24	4		0.06	23.7	23.7		23.3	2.2	5.3	-0.12
1.75	2.75	2.1	15:06:	01:25:43	0.059	23.4	24.1	15		0.06	23.8	23.8		23.6	2.1	5.1	-0.07
2.75	2.75	2.1	14:054	01:13:33	0.063	51	23.9	13		0.064	23.6	23.6		23.1	3.2	5.58	-0.17
3.75	2.75	2.1	14:012	00:31:37	0.054	32.6	24.5	6		0.055	24.2	24.2		23.5	1.4	5.01	-0.02
0.75	3.25	2.1	13:053	00:12:35	0.055	26.6	24.2	3		0.056	23.9	23.9		23.6	1.6	5.06	-0.05
2.25	3.25	2.1	15:031	01:50:37	0.053	38.2	24	19		0.054	23.7	23.7		23.3	1.3	5.33	-0.13
2.75	3.25	2.1	14:048	01:07:34	0.04	76.2	24.1	12		0.041	23.8	23.8		23.2	0	5.28	-0.12
3.75	3.25	2.1	14:018	00:37:34	0.045	66.8	24.2	7		0.046	23.9	23.9		23.4	0	5.15	-0.09
0.75	3.75	2.1	13:046	00:06:16	0.048	33	24.2	2		0.049	23.9	23.9		23.8	0	5.02	-0.03
1.75	3.75	2.1	15:012	01:32:24	0.083	47.6	24.3	16		0.083	24	24		24.6	5.6	5.18	0.09
2.75	3.75	2.1	14:042	01:01:31	0.058	27.7	24.3	11		0.059	24	24		23.3	2	5.13	-0.08
3.75	3.75	2.1	14:024	00:43:35	0.055	42.3	24	8		0.056	23.7	23.7		23.1	1.7	5.47	-0.15
0.75	4.25	2.1	13:040	00:00:00	0.068	39.3	24.1	1		0.069	23.8	23.8		24	3.6	5	-0.01
1.75	4.25	2.1	15:019	01:38:33	0.061	46.5	24.4	17		0.062	24.1	24.1		24	2.7	5.02	0.03
2.25	4.25	2.1	15:025	01:44:33	0.072	39.2	24	18		0.072	23.7	23.7		23.2	4.1	5.36	-0.13
2.75	4.25	2.1	14:035	00:55:28	0.063	47.1	24	10		0.064	23.7	23.7		23.3	3.1	5.29	-0.12
3.75	4.25	2.1	14:030	00:49:33	0.068	42.6	23.8	9		0.069	23.5	23.5		23.3	3.8	5.5	-0.16
49.25	49.25	2.1	15:051	02:11:24	0.046	45.2	24.3	22		0.047	24	24		23.7	0	5.01	-0.02
0.75	0.25	2.6	14:030	00:49:33	0.106	26.6	23.6	9		0.104	23.2	23.2		23.3	7.4	6.21	-0.24
1.75	0.25	2.6	14:035	00:55:28	0.148	21.7	23.9	10		0.151	23.5	23.5		23.3	11	7.21	-0.33
2.75	0.25	2.6	15:019	01:38:33	0.152	21.7	24.3	17		0.155	23.9	23.9		24	11	5.72	-0.19
3.75	0.25	2.6	13:040	00:00:00	0.11	24.2	23.8	1		0.109	23.4	23.4		24	7.5	5.36	-0.13
0.75	0.75	2.6	14:024	00:43:35	0.064	31.8	24.3	8		0.057	23.9	23.9		23.1	1.8	5.29	-0.12
1.75	0.75	2.6	14:042	01:01:31	0.114	22.1	24.8	11		0.113	24.3	24.3		23.3	7.1	5.25	-0.11
2.75	0.75	2.6	15:012	01:32:24	0.168	20.3	24.8	16		0.173	24.3	24.3		24.6	12	5.13	-0.08
3.75	0.75	2.6	13:046	00:06:16	0.131	23	24	2		0.132	23.6	23.6		23.8	9.4	5.89	-0.21
0.75	1.25	2.6	14:018	00:37:34	0.073	36.9	24.3	7		0.067	23.9	23.9		23.4	3.3	5.15	-0.09
1.75	1.25	2.6	14:048	01:07:34	0.086	27.8	24.9	12		0.082	24.4	24.4		23.2	4.5	5.01	-0.02
2.25	1.25	2.6	15:045	02:05:05	0.111	25	24.4	21		0.11	24	24		23.6	7.2	5.23	-0.11
3.75	1.25	2.6	13:053	00:12:35	0.114	29.7	24.2	3		0.113	23.8	23.8		23.6	8.1	5.43	-0.14
0.75	1.75	2.6	14:012	00:31:37	0.089	24.7	24	6		0.085	23.6	23.6		23.5	5.1	5.27	-0.12
1.75	1.75	2.6	14:054	01:13:33	0.092	46.2	23.7	13		0.088	23.3	23.3		23.1	6.6	5.97	-0.22
2.75	1.75	2.6	15:06:	01:25:43	0.116	33.1	24.4	15		0.115	24	24		23.6	8.4	5.28	-0.12
3.75	1.75	2.6	14:00:	00:19:49	0.085	28.2	24.4	4		0.081	24	24		23.3	4.6	5.11	-0.07
0.75	2.25	2.6	14:06:	00:25:43	0.08	29.3	24.6	5		0.075	24.2	24.2		23.1	3.9	5.08	-0.06
1.75	2.25	2.6	14:059	01:19:30	0.111	32.6	23.9	15		0.11	23.5	23.5		23.6	8.2	5.64	-0.18
2.25	2.25	2.6	15:037	01:57:19	0.088	34.7	23.9	20		0.084	23.5	23.5		23.2	5.4	5.58	-0.17
2.75	2.25	2.6	14:059	01:19:30	0.111	32.6	23.9	15		0.11	23.5	23.5		23.6	8.2	5.64	-0.18
3.75	2.25	2.6	14:06:	00:25:43	0.08	29.3	24.6	5		0.075	24.2	24.2		23.1	3.9	5.08	-0.06
0.75	2.75	2.6	14:00:	00:19:49	0.085	28.2	24.4	4		0.081	24	24		23.3	4.6	5.11	-0.07
1.75	2.75	2.6	15:06:	01:25:43	0.116	33.1	24.4	15		0.115	24	24		23.6	8.4	5.28	-0.12
2.75	2.75	2.6	14:054	01:13:33	0.092	46.2	23.7	13		0.088	23.3	23.3		23.1	6.6	5.97	-0.22
3.75	2.75	2.6	14:012	00:31:37	0.089	24.7	24	6		0.085	23.6	23.6		23.5	5.1	5.27	-0.12
0.75	3.25	2.6	13:053	00:12:35	0.114	29.7	24.2	3		0.113	23.8	23.8		23.6	8.1	5.43	-0.14
2.25	3.25	2.6	15:031	01:50:37	0.097	29.7	24.3	19		0.094	23.9	23.9		23.3	6.1	5.26	-0.11
2.75	3.25	2.6	14:048	01:07:34	0.086	27.8	24.9	12		0.082	24.4	24.4		23.2	4.5	5.01	-0.02
3.75	3.25	2.6	14:018	00:37:34	0.073	36.9	24.3	7		0.067	23.9	23.9		23.4	3.3	5.15	-0.09
0.75	3.75	2.6	13:046	00:06:16	0.131	23	24	2		0.132	23.6	23.6		23.8	9.4	5.89	-0.21
1.75	3.75	2.6	15:012	01:32:24	0.168	20.3	24.8	16		0.173	24.3	24.3		24.6	12	5.13	-0.08
2.75	3.75	2.6	14:042	01:01:31	0.114	22.1	24.8	11		0.113	24.3	24.3		23.3	7.1	5.25	-0.11
3.75	3.75	2.6	14:024	00:43:35	0.064	31.8	24.3	8		0.057	23.9	23.9		23.1	1.8	5.29	-0.12
0.75	4.25	2.6	13:040	00:00:00	0.11	24.2	23.8	1		0.109	23.4	23.4		24	7.5	5.36	-0.13
1.75	4.25	2.6	15:019	01:38:33	0.152	21.7	24.3	17		0.155	23.9	23.9		24	11	5.72	-0.19
2.25	4.25	2.6	15:025	01:44:33	0.115	32.7	24.3	18		0.114	23.9	23.9		23.2	8.3	5.66	-0.18
2.75	4.25	2.6	14:035	00:55:28	0.148	21.7	23.9	10		0.151	23.5	23.5		23.3	11	7.21	-0.33
3.75	4.25	2.6	14:030	00:49:33	0.106	26.6	23.6	9		0.104	23.2	23.2		23.3	7.4	6.21	-0.24
49.25	49.25	2.6	15:051	02:11:24	0.093	32.8	24.3	22		0.09	23.9	23.9		23.7	5.8	5.03	-0.04
0.25	0.25	0.1	14:030	00:49:33	0.085	9.5	20.6	9		0.087	20.2	20.2		23.3	6.1	15.5	-0.71
1.25	0.25	0.1	15:019	01:38:33	0.082	12	20.9	17		0.083	20.5	20.5		24	5.8	11.8	-0.57
2.25	0.25	0.1	15:051	02:11:24	0.064	34.2	21.9	22		0.064	21.5	21.5		23.7	3.5	8.98	-0.44
3.25	0.25	0.1	14:035	00:55:28	0.059	18	22.4	10		0.058	21.9	21.9		23.3	2.2	8.59	-0.42
4.25	0.25	0.1	14:030	00:49:33	0.085	9.5	20.6	9		0.087	20.2	20.2		23.3	6.1	15.5	-0.71
0.25	0.75	0.1	14:024	00:43:35	0.047	10.5	20.5	8		0.045	20.1	20.1		23.1	0	16.9	-0.75
1.25	0.75	0.1	15:012	01:32:24	0.077	18	21.6	16		0.078	21.2	21.2		24.6	5.1	7.9	-0.37
2.25	0.75	0.1	15:045	02:05:05	0.057	24.5	22.4	21		0.056	21.9	21.9		23.6	1.9	8.1	-0.39
3.25	0.75	0.1	14:042	01:01:31	0.053	20.7	22.5	11		0.052	22	22		23.3	0.8	8.45	-0.41
4.25	0.75	0.1	14:024	00:43:35	0.047	10.5	20.5	8		0.045	20.1	20.1		23.1	0	16.9	-0.75
0.25	1.25	0.1	14:018	00:37:34	0.084	11.8	20.5	7		0.086	20.1	20.1		23.4	6.2	15.9	-0.72

1.25	1.25	0.1	15:06:	01:25:43	0.076	14.8	20.7	15		0.077	20.3	20.3		23.6	5.2	13.9	-0.65
4.25	1.25	0.1	14:018	00:37:34	0.084	11.8	20.5	7		0.086	20.1	20.1		23.4	6.2	15.9	-0.72
0.25	1.75	0.1	14:012	00:31:37	0.067	6	19.8	6		0.067	19.4	19.4		23.5	3.8	19.2	-0.82
1.25	1.75	0.1	14:059	01:19:30	0.083	8.3	20.4	15		0.085	20	20		23.6	5.9	15.4	-0.7
2.25	1.75	0.1	15:037	01:57:19	0.059	21.4	22.2	20		0.058	21.7	21.7		23.2	2.3	9.51	-0.47
3.25	1.75	0.1	14:048	01:07:34	0.064	23.5	21.6	12		0.064	21.2	21.2		23.2	3.3	11.3	-0.55
4.25	1.75	0.1	14:012	00:31:37	0.067	6	19.8	6		0.067	19.4	19.4		23.5	3.8	19.2	-0.82
0.25	2.25	0.1	14:06:	00:25:43	0.11	10.3	19.1	5		0.114	18.7	18.7		23.1	10	25.5	-0.98
1.25	2.25	0.1	14:054	01:13:33	0.091	10.7	20.8	13		0.093	20.4	20.4		23.1	6.8	15.3	-0.7
3.25	2.25	0.1	14:054	01:13:33	0.091	10.7	20.8	13		0.093	20.4	20.4		23.1	6.8	15.3	-0.7
4.25	2.25	0.1	14:06:	00:25:43	0.11	10.3	19.1	5		0.114	18.7	18.7		23.1	10	25.5	-0.98
0.25	2.75	0.1	14:00:	00:19:49	0.046	6.1	20.3	4		0.044	19.9	19.9		23.3	0	17	-0.76
1.25	2.75	0.1	14:048	01:07:34	0.064	23.5	21.6	12		0.064	21.2	21.2		23.2	3.3	11.3	-0.55
2.25	2.75	0.1	15:031	01:50:37	0.058	31.6	21.2	19		0.057	20.8	20.8		23.3	2.3	12.8	-0.61
3.25	2.75	0.1	14:059	01:19:30	0.083	8.3	20.4	15		0.085	20	20		23.6	5.9	15.4	-0.7
4.25	2.75	0.1	14:00:	00:19:49	0.046	6.1	20.3	4		0.044	19.9	19.9		23.3	0	17	-0.76
0.25	3.25	0.1	13:053	00:12:35	0.06	12.6	20.2	3		0.059	19.8	19.8		23.6	2.7	16.5	-0.74
3.25	3.25	0.1	15:06:	01:25:43	0.076	14.8	20.7	15		0.077	20.3	20.3		23.6	5.2	13.9	-0.65
4.25	3.25	0.1	13:053	00:12:35	0.06	12.6	20.2	3		0.059	19.8	19.8		23.6	2.7	16.5	-0.74
0.25	3.75	0.1	13:046	00:06:16	0.048	0	22	2		0.046	21.6	21.6		23.8	0	8.56	-0.41
1.25	3.75	0.1	14:042	01:01:31	0.053	20.7	22.5	11		0.052	22	22		23.3	0.8	8.45	-0.41
2.25	3.75	0.1	15:025	01:44:33	0.076	18.4	21.2	18		0.077	20.8	20.8		23.2	5.1	12.9	-0.61
3.25	3.75	0.1	15:012	01:32:24	0.077	18	21.6	16		0.078	21.2	21.2		24.6	5.1	7.9	-0.37
4.25	3.75	0.1	13:046	00:06:16	0.048	0	22	2		0.046	21.6	21.6		23.8	0	8.56	-0.41
0.25	4.25	0.1	13:040	00:00:00	0.055	5.1	20	1		0.054	19.6	19.6		24	1.5	15.9	-0.72
1.25	4.25	0.1	14:035	00:55:28	0.059	18	22.4	10		0.058	21.9	21.9		23.3	2.2	8.59	-0.42
3.25	4.25	0.1	15:019	01:38:33	0.082	12	20.9	17		0.083	20.5	20.5		24	5.8	11.8	-0.57
4.25	4.25	0.1	13:040	00:00:00	0.055	5.1	20	1		0.054	19.6	19.6		24	1.5	15.9	-0.72
0.25	0.25	0.6	14:030	00:49:33	0.047	18.2	23.3	9	22.91	0.038	22.7	22.7	22.91	23	0	7.13	-0.32
1.25	0.25	0.6	15:019	01:38:33	0.044	10.1	23.2	17	22.52	0.035	22.6	22.6	22.52	22.5	0	8.45	-0.41
2.25	0.25	0.6	15:051	02:11:24	0.048	25.8	22.9	22	22.84	0.039	22.3	22.3	22.84	23.2	0	7.82	-0.37
3.25	0.25	0.6	14:035	00:55:28	0.056	24.7	23.2	10	23.22	0.047	22.6	22.6	23.22	23.7	0	6.4	-0.26
4.25	0.25	0.6	14:030	00:49:33	0.047	18.2	23.3	9	22.91	0.038	22.7	22.7	22.91	23	0	7.13	-0.32
0.25	0.75	0.6	14:024	00:43:35	0.047	18.1	23.4	8	22.89	0.038	22.8	22.8	22.89	23	0	7.05	-0.31
1.25	0.75	0.6	15:012	01:32:24	0.049	12.9	23.2	16	22.55	0.04	22.6	22.6	22.55	22.5	0	8.35	-0.4
2.25	0.75	0.6	15:045	02:05:05	0.047	24.8	23.2	21	22.87	0.038	22.6	22.6	22.87	23	0	7.35	-0.34
3.25	0.75	0.6	14:042	01:01:31	0.075	22	22.8	11	23.45	0.066	22.2	22.2	23.45	24.5	3.4	6.04	-0.22
4.25	0.75	0.6	14:024	00:43:35	0.047	18.1	23.4	8	22.89	0.038	22.8	22.8	22.89	23	0	7.05	-0.31
0.25	1.25	0.6	14:018	00:37:34	0.051	22.8	23.1	7	22.81	0.042	22.5	22.5	22.81	23	0	7.65	-0.36
1.25	1.25	0.6	15:06:	01:25:43	0.044	15.7	23.2	15	22.65	0.035	22.6	22.6	22.65	22.7	0	8.02	-0.38
4.25	1.25	0.6	14:018	00:37:34	0.051	22.8	23.1	7	22.81	0.042	22.5	22.5	22.81	23	0	7.65	-0.36
0.25	1.75	0.6	14:012	00:31:37	0.05	27	23.2	6	22.61	0.041	22.6	22.6	22.61	22.6	0	8.14	-0.39
1.25	1.75	0.6	14:059	01:19:30	0.043	10.5	23.2	15	22.87	0.034	22.6	22.6	22.87	23	0	7.38	-0.34
2.25	1.75	0.6	15:037	01:57:19	0.045	12.5	23.2	20	22.61	0.036	22.6	22.6	22.61	22.6	0	8.14	-0.39
3.25	1.75	0.6	14:048	01:07:34	0.044	15	23.2	12	23.16	0.035	22.6	22.6	23.16	23.5	0	6.62	-0.28
4.25	1.75	0.6	14:012	00:31:37	0.05	27	23.2	6	22.61	0.041	22.6	22.6	22.61	22.6	0	8.14	-0.39
0.25	2.25	0.6	14:06:	00:25:43	0.039	36.8	23.4	5	22.67	0.03	22.8	22.8	22.67	22.6	0	7.67	-0.36
1.25	2.25	0.6	14:054	01:13:33	0.044	13.8	23.2	13	22.94	0.035	22.6	22.6	22.94	23.1	0	7.18	-0.32
3.25	2.25	0.6	14:054	01:13:33	0.044	13.8	23.2	13	22.94	0.035	22.6	22.6	22.94	23.1	0	7.18	-0.32
4.25	2.25	0.6	14:06:	00:25:43	0.039	36.8	23.4	5	22.67	0.03	22.8	22.8	22.67	22.6	0	7.67	-0.36
0.25	2.75	0.6	14:00:	00:19:49	0.044	27.2	23.2	4	22.64	0.035	22.6	22.6	22.64	22.7	0	8.05	-0.38
1.25	2.75	0.6	14:048	01:07:34	0.044	15	23.2	12	23.16	0.035	22.6	22.6	23.16	23.5	0	6.62	-0.28
2.25	2.75	0.6	15:031	01:50:37	0.044	18.7	23.2	19	22.65	0.035	22.6	22.6	22.65	22.7	0	8.02	-0.38
3.25	2.75	0.6	14:059	01:19:30	0.043	10.5	23.2	15	22.87	0.034	22.6	22.6	22.87	23	0	7.38	-0.34
4.25	2.75	0.6	14:00:	00:19:49	0.044	27.2	23.2	4	22.64	0.035	22.6	22.6	22.64	22.7	0	8.05	-0.38
0.25	3.25	0.6	13:053	00:12:35	0.047	29.5	23.2	3	22.62	0.038	22.6	22.6	22.62	22.6	0	8.12	-0.39
3.25	3.25	0.6	15:06:	01:25:43	0.044	15.7	23.2	15	22.65	0.035	22.6	22.6	22.65	22.7	0	8.02	-0.38
4.25	3.25	0.6	13:053	00:12:35	0.047	29.5	23.2	3	22.62	0.038	22.6	22.6	22.62	22.6	0	8.12	-0.39
0.25	3.75	0.6	13:046	00:06:16	0.069	34.9	23.5	2	22.66	0.06	22.9	22.9	22.66	22.5	2.6	7.65	-0.36
1.25	3.75	0.6	14:042	01:01:31	0.075	22	22.8	11	23.45	0.066	22.2	22.2	23.45	24.5	3.4	6.04	-0.22
2.25	3.75	0.6	15:025	01:44:33	0.045	15.5	23.2	18	22.74	0.036	22.6	22.6	22.74	22.8	0	7.76	-0.36
3.25	3.75	0.6	15:012	01:32:24	0.049	12.9	23.2	16	22.55	0.04	22.6	22.6	22.55	22.5	0	8.35	-0.4
4.25	3.75	0.6	13:046	00:06:16	0.069	34.9	23.5	2	22.66	0.06	22.9	22.9	22.66	22.5	2.6	7.65	-0.36
0.25	4.25	0.6	13:040	00:00:00	0.044	33.7	23.1	1	22.42	0.035	22.5	22.5	22.42	22.4	0	8.97	-0.44
1.25	4.25	0.6	14:035	00:55:28	0.056	24.7	23.2	10	23.22	0.047	22.6	22.6	23.22	23.7	0	6.4	-0.26
3.25	4.25	0.6	15:019	01:38:33	0.044	10.1	23.2	17	22.52	0.035	22.6	22.6	22.52	22.5	0	8.45	-0.41
4.25	4.25	0.6	13:040	00:00:00	0.044	33.7	23.1	1	22.42	0.035	22.5	22.5	22.42	22.4	0	8.97	-0.44
0.25	0.25	1.1	14:030	00:49:33	0.049	50	24.3	9	23.66	0.049	23.9	23.9	23.66	23.5	0	5.09	-0.07
1.25	0.25	1.1	15:019	01:38:33	0.082	35.4	23.7	17	23.06	0.083	23.3	23.3	23.06	22.8	5.4	6.26	-0.25
2.25	0.25	1.1	15:051	02:11:24	0.085	24.9	23.6	22	23.5	0.086	23.2	23.2	23.5	23.8	5.4	5.44	-0.15

3.25	0.25	1.1	14:035	00:55:28	0.102	28.4	24.5	10	24.18	0.103	24.1	24.1	24.18	24.3	6.8	5.01	0.02
4.25	0.25	1.1	14:030	00:49:33	0.049	50	24.3	9	23.66	0.049	23.9	23.9	23.66	23.5	0	5.09	-0.07
0.25	0.75	1.1	14:024	00:43:35	0.054	31.5	24.5	8	23.8	0.054	24.1	24.1	23.8	23.6	1.3	5.01	-0.02
1.25	0.75	1.1	15:012	01:32:24	0.065	42.5	23.9	16	23.11	0.066	23.5	23.5	23.11	22.8	3.3	6	-0.22
2.25	0.75	1.1	15:045	02:05:05	0.05	26.8	24.4	21	23.46	0.05	24	24	23.46	23.1	0.3	5.22	-0.1
3.25	0.75	1.1	14:042	01:01:31	0.052	29	24.6	11	24.57	0.052	24.2	24.2	24.57	24.8	0.9	5.48	0.15
4.25	0.75	1.1	14:024	00:43:35	0.054	31.5	24.5	8	23.8	0.054	24.1	24.1	23.8	23.6	1.3	5.01	-0.02
0.25	1.25	1.1	14:018	00:37:34	0.045	28	24.4	7	23.74	0.045	24	24	23.74	23.6	0	5.04	-0.04
1.25	1.25	1.1	15:06:	01:25:43	0.051	42.7	24.1	15	23.27	0.051	23.7	23.7	23.27	23	0.7	5.57	-0.17
4.25	1.25	1.1	14:018	00:37:34	0.045	28	24.4	7	23.74	0.045	24	24	23.74	23.6	0	5.04	-0.04
0.25	1.75	1.1	14:012	00:31:37	0.039	46.6	24.3	6	23.35	0.039	23.9	23.9	23.35	23	0	5.33	-0.13
1.25	1.75	1.1	14:059	01:19:30	0.039	20	24.5	15	23.6	0.039	24.1	24.1	23.6	23.3	0	5.07	-0.06
2.25	1.75	1.1	15:037	01:57:19	0.048	41.6	24.3	20	23.35	0.048	23.9	23.9	23.35	23	0	5.36	-0.13
3.25	1.75	1.1	14:048	01:07:34	0.044	24.2	24.7	12	24.2	0.044	24.3	24.3	24.2	24.1	0	5.13	0.08
4.25	1.75	1.1	14:012	00:31:37	0.039	46.6	24.3	6	23.35	0.039	23.9	23.9	23.35	23	0	5.33	-0.13
0.25	2.25	1.1	14:06:	00:25:43	0.064	44.1	23.9	5	23.39	0.065	23.5	23.5	23.39	23.3	3.2	5.5	-0.16
1.25	2.25	1.1	14:054	01:13:33	0.041	18.3	24.5	13	23.77	0.041	24.1	24.1	23.77	23.6	0	5.01	-0.03
3.25	2.25	1.1	14:054	01:13:33	0.041	18.3	24.5	13	23.77	0.041	24.1	24.1	23.77	23.6	0	5.01	-0.03
4.25	2.25	1.1	14:06:	00:25:43	0.064	44.1	23.9	5	23.39	0.065	23.5	23.5	23.39	23.3	3.2	5.5	-0.16
0.25	2.75	1.1	14:00:	00:19:49	0.087	27.6	23.8	4	23.29	0.088	23.4	23.4	23.29	23.2	5.6	5.72	-0.19
1.25	2.75	1.1	14:048	01:07:34	0.044	24.2	24.7	12	24.2	0.044	24.3	24.3	24.2	24.1	0	5.13	0.08
2.25	2.75	1.1	15:031	01:50:37	0.038	22.1	24.5	19	23.24	0.038	24.1	24.1	23.24	22.7	0	5.36	-0.13
3.25	2.75	1.1	14:059	01:19:30	0.039	20	24.5	15	23.6	0.039	24.1	24.1	23.6	23.3	0	5.07	-0.06
4.25	2.75	1.1	14:00:	00:19:49	0.087	27.6	23.8	4	23.29	0.088	23.4	23.4	23.29	23.2	5.6	5.72	-0.19
0.25	3.25	1.1	13:053	00:12:35	0.085	30.9	23.7	3	23.25	0.086	23.3	23.3	23.25	23.2	5.6	5.84	-0.2
3.25	3.25	1.1	15:06:	01:25:43	0.051	42.7	24.1	15	23.27	0.051	23.7	23.7	23.27	23	0.7	5.57	-0.17
4.25	3.25	1.1	13:053	00:12:35	0.085	30.9	23.7	3	23.25	0.086	23.3	23.3	23.25	23.2	5.6	5.84	-0.2
0.25	3.75	1.1	13:046	00:06:16	0.076	38.8	23.6	2	23.36	0.077	23.2	23.2	23.36	23.5	4.8	5.67	-0.18
1.25	3.75	1.1	14:042	01:01:31	0.052	29	24.6	11	24.57	0.052	24.2	24.2	24.57	24.8	0.9	5.48	0.15
2.25	3.75	1.1	15:025	01:44:33	0.036	37	24.3	18	23.19	0.036	23.9	23.9	23.19	22.8	0	5.52	-0.16
3.25	3.75	1.1	15:012	01:32:24	0.065	42.5	23.9	16	23.11	0.066	23.5	23.5	23.11	22.8	3.3	6	-0.22
4.25	3.75	1.1	13:046	00:06:16	0.076	38.8	23.6	2	23.36	0.077	23.2	23.2	23.36	23.5	4.8	5.67	-0.18
0.25	4.25	1.1	13:040	00:00:00	0.081	58.2	23.9	1	23.4	0.082	23.5	23.5	23.4	23.3	6.1	5.5	-0.16
1.25	4.25	1.1	14:035	00:55:28	0.102	28.4	24.5	10	24.18	0.103	24.1	24.1	24.18	24.3	6.8	5.01	0.02
3.25	4.25	1.1	15:019	01:38:33	0.082	35.4	23.7	17	23.06	0.083	23.3	23.3	23.06	22.8	5.4	6.26	-0.25
4.25	4.25	1.1	13:040	00:00:00	0.081	58.2	23.9	1	23.4	0.082	23.5	23.5	23.4	23.3	6.1	5.5	-0.16
0.25	0.25	1.7	14:030	00:49:33	0.047	60.8	24.3	9		0.048	23.9	23.9		23.5	0	5.09	-0.07
1.25	0.25	1.7	15:019	01:38:33	0.062	28.7	24.1	17		0.064	23.7	23.7		22.8	2.7	5.68	-0.18
2.25	0.25	1.7	15:051	02:11:24	0.051	29.9	24.2	22		0.052	23.8	23.8		23.8	0.9	5.05	-0.05
3.25	0.25	1.7	14:035	00:55:28	0.152	17.5	24.4	10		0.157	24	24		24.3	10	5.42	-0.14
4.25	0.25	1.7	14:030	00:49:33	0.047	60.8	24.3	9		0.048	23.9	23.9		23.5	0	5.09	-0.07
0.25	0.75	1.7	14:024	00:43:35	0.053	41.3	24.3	8		0.054	23.9	23.9		23.6	1.4	5.06	-0.06
1.25	0.75	1.7	15:012	01:32:24	0.034	48.5	24.3	16		0.035	23.9	23.9		22.8	0	5.5	-0.16
2.25	0.75	1.7	15:045	02:05:05	0.042	37.3	24.4	21		0.043	24	24		23.1	0	5.22	-0.1
3.25	0.75	1.7	14:042	01:01:31	0.075	29.3	24.3	11		0.077	23.9	23.9		24.8	4.3	5.22	0.1
4.25	0.75	1.7	14:024	00:43:35	0.053	41.3	24.3	8		0.054	23.9	23.9		23.6	1.4	5.06	-0.06
0.25	1.25	1.7	14:018	00:37:34	0.063	21.2	24.3	7		0.065	23.9	23.9		23.6	2.7	5.07	-0.06
1.25	1.25	1.7	15:06:	01:25:43	0.04	53.4	24.3	15		0.041	23.9	23.9		23.3	0	5.18	-0.09
4.25	1.25	1.7	14:018	00:37:34	0.063	21.2	24.3	7		0.065	23.9	23.9		23.6	2.7	5.07	-0.06
0.25	1.75	1.7	14:012	00:31:37	0.048	42.5	24.4	6		0.049	24	24		23	0	5.26	-0.11
1.25	1.75	1.7	14:059	01:19:30	0.051	35.3	24.4	15		0.052	24	24		23.3	0.9	5.12	-0.08
2.25	1.75	1.7	15:037	01:57:19	0.033	44.6	24.5	20		0.034	24.1	24.1		23	0	5.21	-0.1
3.25	1.75	1.7	14:048	01:07:34	0.043	38.1	24.7	12		0.044	24.3	24.3		24.1	0	5.13	0.08
4.25	1.75	1.7	14:012	00:31:37	0.048	42.5	24.4	6		0.049	24	24		23	0	5.26	-0.11
0.25	2.25	1.7	14:06:	00:25:43	0.051	40.6	24.3	5		0.052	23.9	23.9		23.3	0.9	5.17	-0.09
1.25	2.25	1.7	14:054	01:13:33	0.038	35.5	24.6	13		0.039	24.2	24.2		23.6	0	5	-0.01
3.25	2.25	1.7	14:054	01:13:33	0.038	35.5	24.6	13		0.039	24.2	24.2		23.6	0	5	-0.01
4.25	2.25	1.7	14:06:	00:25:43	0.051	40.6	24.3	5		0.052	23.9	23.9		23.3	0.9	5.17	-0.09
0.25	2.75	1.7	14:00:	00:19:49	0.065	31.4	24.2	4		0.067	23.8	23.8		23.2	3.2	5.3	-0.12
1.25	2.75	1.7	14:048	01:07:34	0.043	38.1	24.7	12		0.044	24.3	24.3		24.1	0	5.13	0.08
2.25	2.75	1.7	15:031	01:50:37	0.04	25.2	24.3	19		0.041	23.9	23.9		22.7	0	5.56	-0.17
3.25	2.75	1.7	14:059	01:19:30	0.051	35.3	24.4	15		0.052	24	24		23.3	0.9	5.12	-0.08
4.25	2.75	1.7	14:00:	00:19:49	0.065	31.4	24.2	4		0.067	23.8	23.8		23.2	3.2	5.3	-0.12
0.25	3.25	1.7	13:053	00:12:35	0.056	47.6	24.2	3		0.057	23.8	23.8		23.2	2	5.3	-0.12
3.25	3.25	1.7	15:06:	01:25:43	0.04	53.4	24.3	15		0.041	23.9	23.9		23.3	0	5.18	-0.09
4.25	3.25	1.7	13:053	00:12:35	0.056	47.6	24.2	3		0.057	23.8	23.8		23.2	2	5.3	-0.12
0.25	3.75	1.7	13:046	00:06:16	0.044	55.8	24	2		0.045	23.6	23.6		23.5	0	5.27	-0.12
1.25	3.75	1.7	14:042	01:01:31	0.075	29.3	24.3	11		0.077	23.9	23.9		24.8	4.3	5.22	0.1
2.25	3.75	1.7	15:025	01:44:33	0.039	45.6	24.3	18		0.04	23.9	23.9		22.8	0	5.52	-0.16
3.25	3.75	1.7	15:012	01:32:24	0.034	48.5	24.3	16		0.035	23.9	23.9		22.8	0	5.5	-0.16

4.25	3.75	1.7	13:046	00:06:16	0.044	55.8	24	2		0.045	23.6	23.6		23.5	0	5.27	-0.12
0.25	4.25	1.7	13:040	00:00:00	0.109	29.9	23.5	1		0.112	23.1	23.1		23.3	8.6	6.68	-0.28
1.25	4.25	1.7	14:035	00:55:28	0.152	17.5	24.4	10		0.157	24	24		24.3	10	5.42	-0.14
3.25	4.25	1.7	15:019	01:38:33	0.062	28.7	24.1	17		0.064	23.7	23.7		22.8	2.7	5.68	-0.18
4.25	4.25	1.7	13:040	00:00:00	0.109	29.9	23.5	1		0.112	23.1	23.1		23.3	8.6	6.68	-0.28
0.25	0.25	2.1	14:030	00:49:33	0.063	48.8	23.9	9		0.063	23.7	23.7		23.5	3	5.21	-0.1
1.25	0.25	2.1	15:019	01:38:33	0.088	34.2	23.8	17		0.088	23.6	23.6		22.8	5.8	5.8	-0.2
2.25	0.25	2.1	15:051	02:11:24	0.085	29.1	24	22		0.085	23.8	23.8		23.8	5.2	5.05	-0.05
3.25	0.25	2.1	14:035	00:55:28	0.13	27.6	23.9	10		0.128	23.7	23.7		24.3	9.5	5.29	-0.12
4.25	0.25	2.1	14:030	00:49:33	0.063	48.8	23.9	9		0.063	23.7	23.7		23.5	3	5.21	-0.1
0.25	0.75	2.1	14:024	00:43:35	0.061	38.1	24.1	8		0.061	23.9	23.9		23.6	2.5	5.06	-0.06
1.25	0.75	2.1	15:012	01:32:24	0.049	44.1	23.9	16		0.05	23.7	23.7		22.8	0	5.72	-0.19
2.25	0.75	2.1	15:045	02:05:05	0.058	27.6	24	21		0.059	23.8	23.8		23.1	2	5.38	-0.14
3.25	0.75	2.1	14:042	01:01:31	0.105	33.9	23.9	11		0.104	23.7	23.7		24.8	7.5	5.02	0.03
4.25	0.75	2.1	14:024	00:43:35	0.061	38.1	24.1	8		0.061	23.9	23.9		23.6	2.5	5.06	-0.06
0.25	1.25	2.1	14:018	00:37:34	0.073	24	24.4	7		0.073	24.2	24.2		23.6	3.6	5	-0.01
1.25	1.25	2.1	15:06:	01:25:43	0.047	58	23.9	15		0.048	23.7	23.7		23.3	0	5.32	-0.13
4.25	1.25	2.1	14:018	00:37:34	0.073	24	24.4	7		0.073	24.2	24.2		23.6	3.6	5	-0.01
0.25	1.75	2.1	14:012	00:31:37	0.062	31.8	24.2	6		0.062	24	24		23	2.6	5.26	-0.11
1.25	1.75	2.1	14:059	01:19:30	0.054	19.6	24.3	15		0.055	24.1	24.1		23.3	1.3	5.07	-0.06
2.25	1.75	2.1	15:037	01:57:19	0.052	46.8	23.9	20		0.053	23.7	23.7		23	1.1	5.56	-0.17
3.25	1.75	2.1	14:048	01:07:34	0.062	34.2	23.9	12		0.062	23.7	23.7		24.1	2.7	5.01	-0.02
4.25	1.75	2.1	14:012	00:31:37	0.062	31.8	24.2	6		0.062	24	24		23	2.6	5.26	-0.11
0.25	2.25	2.1	14:06:	00:25:43	0.04	41.6	24.1	5		0.041	23.9	23.9		23.3	0	5.17	-0.09
1.25	2.25	2.1	14:054	01:13:33	0.047	23.3	24.3	13		0.048	24.1	24.1		23.6	0	5.01	-0.03
3.25	2.25	2.1	14:054	01:13:33	0.047	23.3	24.3	13		0.048	24.1	24.1		23.6	0	5.01	-0.03
4.25	2.25	2.1	14:06:	00:25:43	0.04	41.6	24.1	5		0.041	23.9	23.9		23.3	0	5.17	-0.09
0.25	2.75	2.1	14:00:	00:19:49	0.057	23.8	24	4		0.058	23.8	23.8		23.2	1.8	5.3	-0.12
1.25	2.75	2.1	14:048	01:07:34	0.062	34.2	23.9	12		0.062	23.7	23.7		24.1	2.7	5.01	-0.02
2.25	2.75	2.1	15:031	01:50:37	0.044	39.1	24.2	19		0.045	24	24		22.7	0	5.45	-0.15
3.25	2.75	2.1	14:059	01:19:30	0.054	19.6	24.3	15		0.055	24.1	24.1		23.3	1.3	5.07	-0.06
4.25	2.75	2.1	14:00:	00:19:49	0.057	23.8	24	4		0.058	23.8	23.8		23.2	1.8	5.3	-0.12
0.25	3.25	2.1	13:053	00:12:35	0.048	38.5	24	3		0.049	23.8	23.8		23.2	0	5.3	-0.12
3.25	3.25	2.1	15:06:	01:25:43	0.047	58	23.9	15		0.048	23.7	23.7		23.3	0	5.32	-0.13
4.25	3.25	2.1	13:053	00:12:35	0.048	38.5	24	3		0.049	23.8	23.8		23.2	0	5.3	-0.12
0.25	3.75	2.1	13:046	00:06:16	0.053	51.8	23.9	2		0.054	23.7	23.7		23.5	1.3	5.2	-0.1
1.25	3.75	2.1	14:042	01:01:31	0.105	33.9	23.9	11		0.104	23.7	23.7		24.8	7.5	5.02	0.03
2.25	3.75	2.1	15:025	01:44:33	0.068	32.6	23.9	18		0.068	23.7	23.7		22.8	3.4	5.76	-0.19
3.25	3.75	2.1	15:012	01:32:24	0.049	44.1	23.9	16		0.05	23.7	23.7		22.8	0	5.72	-0.19
4.25	3.75	2.1	13:046	00:06:16	0.053	51.8	23.9	2		0.054	23.7	23.7		23.5	1.3	5.2	-0.1
0.25	4.25	2.1	13:040	00:00:00	0.098	37.4	23.1	1		0.097	22.9	22.9		23.3	7.5	6.41	-0.26
1.25	4.25	2.1	14:035	00:55:28	0.13	27.6	23.9	10		0.128	23.7	23.7		24.3	9.5	5.29	-0.12
3.25	4.25	2.1	15:019	01:38:33	0.088	34.2	23.8	17		0.088	23.6	23.6		22.8	5.8	5.8	-0.2
4.25	4.25	2.1	13:040	00:00:00	0.098	37.4	23.1	1		0.097	22.9	22.9		23.3	7.5	6.41	-0.26
0.25	0.25	2.6	14:030	00:49:33	0.065	46.7	25	9		0.075	24.4	24.4		23.5	4.3	5	0.01
1.25	0.25	2.6	15:019	01:38:33	0.113	23.6	23.9	17		0.123	23.3	23.3		22.8	8.9	7.49	-0.35
2.25	0.25	2.6	15:051	02:11:24	0.062	44	25.6	22		0.072	25	25		23.8	3.6	5.45	0.15
3.25	0.25	2.6	14:035	00:55:28	0.12	26.6	25.4	10		0.13	24.8	24.8		24.3	8.5	5.06	0.05
4.25	0.25	2.6	14:030	00:49:33	0.065	46.7	25	9		0.075	24.4	24.4		23.5	4.3	5	0.01
0.25	0.75	2.6	14:024	00:43:35	0.075	36.9	24.9	8		0.085	24.3	24.3		23.6	5.2	5	0.01
1.25	0.75	2.6	15:012	01:32:24	0.088	30	24.1	16		0.098	23.5	23.5		22.8	6.8	6.24	-0.24
2.25	0.75	2.6	15:045	02:05:05	0.065	28.7	25.7	21		0.075	25.1	25.1		23.1	3.5	5.11	0.07
3.25	0.75	2.6	14:042	01:01:31	0.114	40.8	25.5	11		0.124	24.9	24.9		24.8	9.1	5.51	0.16
4.25	0.75	2.6	14:024	00:43:35	0.075	36.9	24.9	8		0.085	24.3	24.3		23.6	5.2	5	0.01
0.25	1.25	2.6	14:018	00:37:34	0.087	27.7	24.8	7		0.097	24.2	24.2		23.6	6.1	5.03	-0.04
1.25	1.25	2.6	15:06:	01:25:43	0.062	56.4	24.9	15		0.072	24.3	24.3		23.3	4.2	5.02	-0.03
4.25	1.25	2.6	14:018	00:37:34	0.087	27.7	24.8	7		0.097	24.2	24.2		23.6	6.1	5.03	-0.04
0.25	1.75	2.6	14:012	00:31:37	0.072	25.9	24.6	6		0.082	24	24		23	4.6	5.26	-0.11
1.25	1.75	2.6	14:059	01:19:30	0.098	22.3	25	15		0.108	24.4	24.4		23.3	6.6	5.12	-0.08
2.25	1.75	2.6	15:037	01:57:19	0.055	34	25.6	20		0.064	25	25		23	2.6	5.04	0.04
3.25	1.75	2.6	14:048	01:07:34	0.11	31.6	25.1	12		0.12	24.5	24.5		24.1	8.3	5	0.01
4.25	1.75	2.6	14:012	00:31:37	0.072	25.9	24.6	6		0.082	24	24		23	4.6	5.26	-0.11
0.25	2.25	2.6	14:06:	00:25:43	0.076	32.6	24.5	5		0.086	23.9	23.9		23.3	5.3	5.17	-0.09
1.25	2.25	2.6	14:054	01:13:33	0.1	24.7	25.1	13		0.11	24.5	24.5		23.6	6.9	5.02	-0.03
3.25	2.25	2.6	14:054	01:13:33	0.1	24.7	25.1	13		0.11	24.5	24.5		23.6	6.9	5.02	-0.03
4.25	2.25	2.6	14:06:	00:25:43	0.076	32.6	24.5	5		0.086	23.9	23.9		23.3	5.3	5.17	-0.09
0.25	2.75	2.6	14:00:	00:19:49	0.089	31.7	24.2	4		0.099	23.6	23.6		23.2	6.9	5.68	-0.18
1.25	2.75	2.6	14:048	01:07:34	0.11	31.6	25.1	12		0.12	24.5	24.5		24.1	8.3	5	0.01
2.25	2.75	2.6	15:031	01:50:37	0.048	55.8	24.7	19		0.057	24.1	24.1		22.7	2	5.36	-0.13
3.25	2.75	2.6	14:059	01:19:30	0.098	22.3	25	15		0.108	24.4	24.4		23.3	6.6	5.12	-0.08
4.25	2.75	2.6	14:00:	00:19:49	0.089	31.7	24.2	4		0.099	23.6	23.6		23.2	6.9	5.68	-0.18
0.25	3.25	2.6	13:053	00:12:35	0.081	29.8	24	3		0.091	23.4	23.4		23.2	6	5.71	-0.19

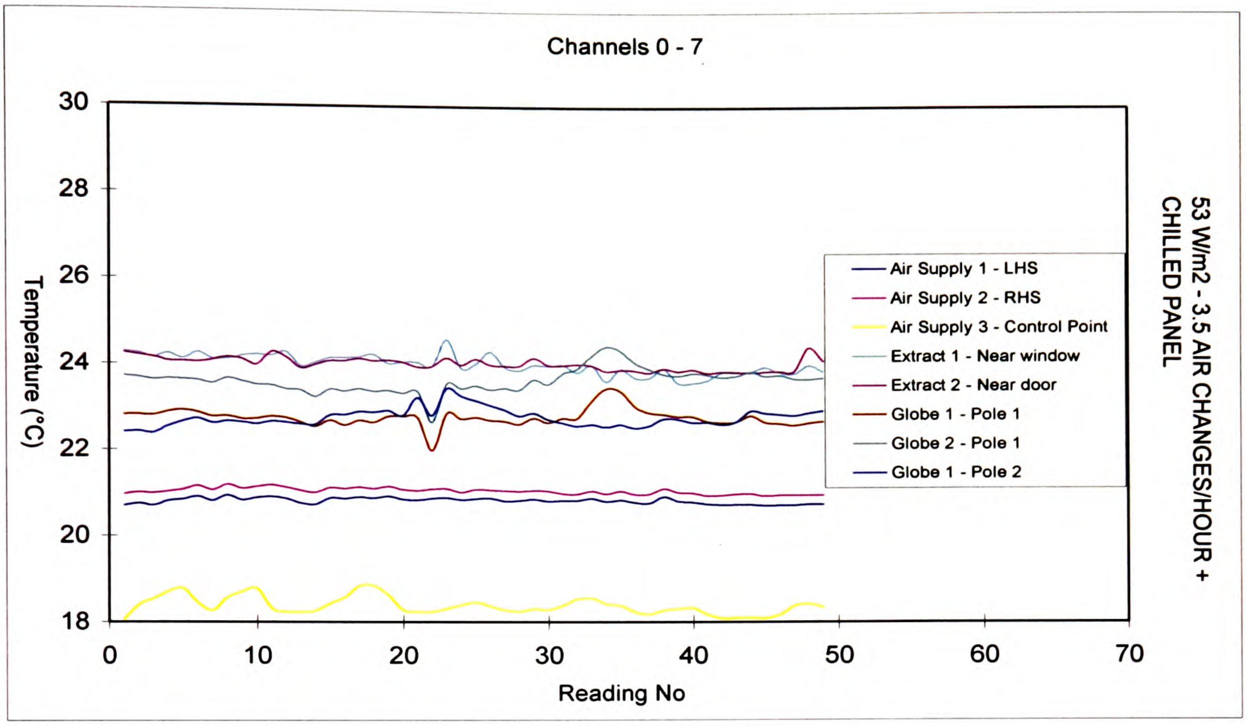
Room Temperature Data (Surface Thermocouples)

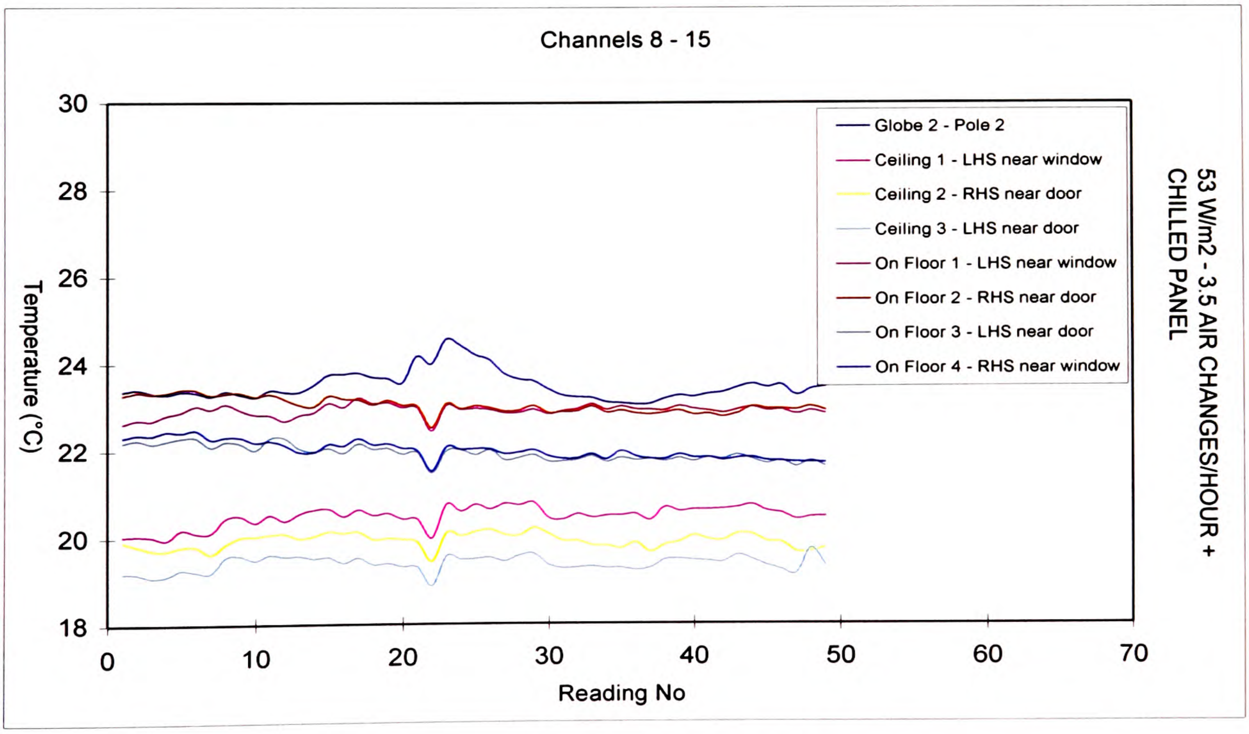
Experiment 4 - 53 W/m^2 with 3.5 air changes per hour plus chilled panels

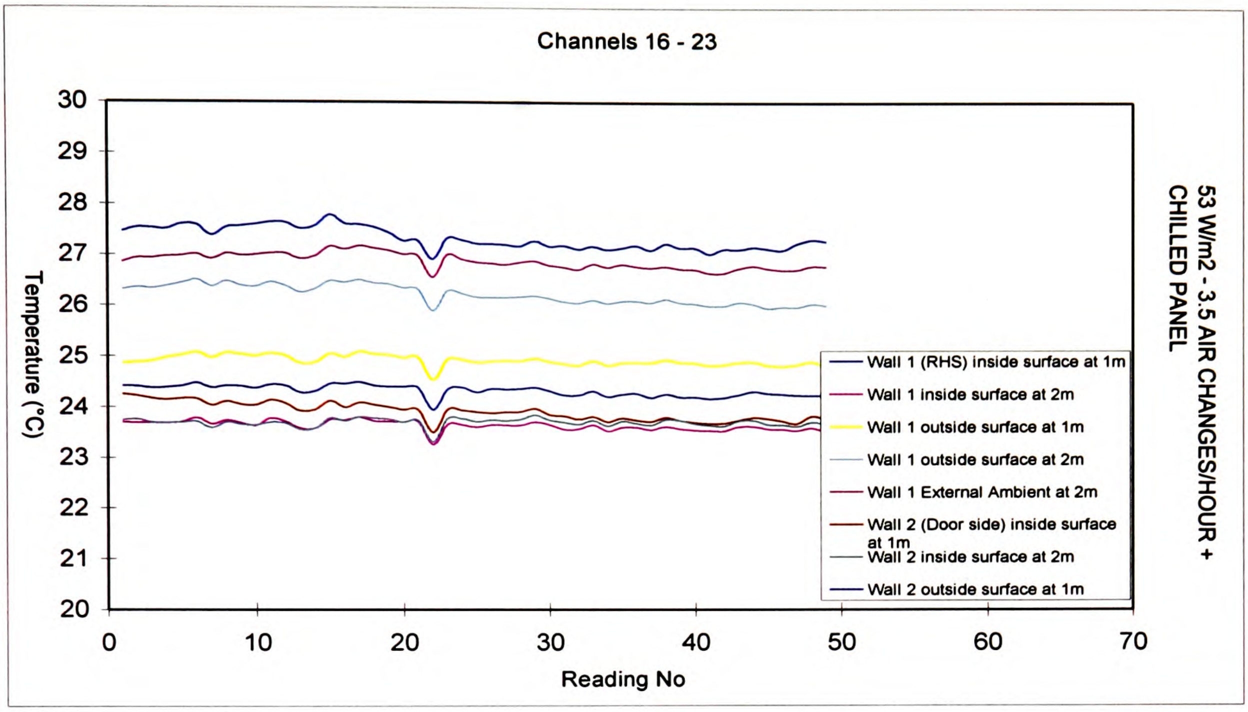
Real time heat loss calculations highlighted in green

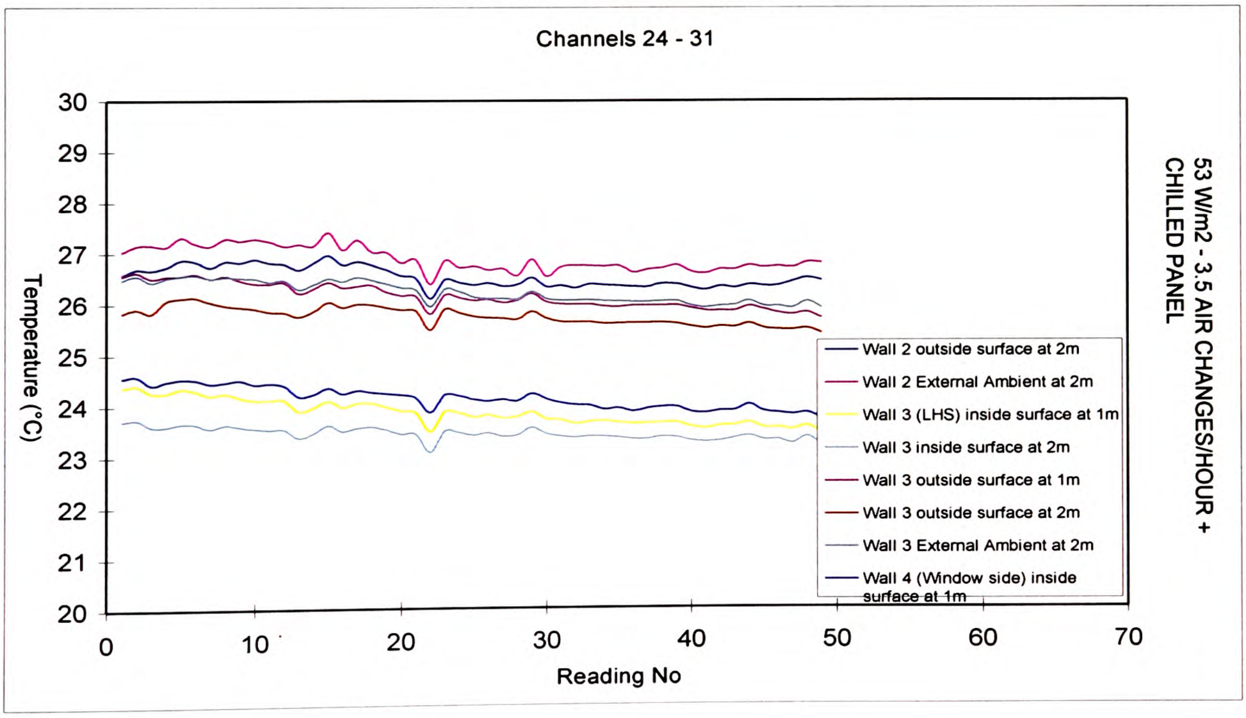
Channel	Location	Temp (°C)		A Positive figure indicates flux into the facility			
CH0	Air Supply 1 - LHS	20.75					
CH1	Air Supply 2 - RHS	20.97					
CH2	Air Supply Andrew Geens	18.34	Fluxes	Area	ΔT	U-value	Flux
CH3	Extract 1 - Near window	23.83		(m^2)	(°C)	(W/m2K)	(W)
CH4	Extract 2 - Near door	24.07					
CH5	Globe 1 - Pole 1	22.68	Floor 1	5.0625	-1.73	0.715	-6.26376
CH6	Globe 2 - Pole 1	23.69	Floor 2	5.0625	-1.79	0.715	-6.46878
CH7	Globe 1 - Pole 2	22.92	Floor 3	5.0625	-0.47	0.715	-1.71794
CH8	Globe 2 - Pole 2	23.46	Floor 4	5.0625	-0.51	0.715	-1.83812
CH9	Ceiling 1 - LHS near window	20.48	Roof	20.25	2.79	1.21	68.3749
CH10	Ceiling 2 - RHS near door	19.74	Wall 1 @ 2.9	1.8	0.55	0.717	0.71588
CH11	Ceiling 3 - LHS near door	19.33	Wall 1 @ 2m	12.85	2.49	0.717	22.97064
CH12	On Floor 1 - LHS near window	22.85	Wall 1 averag	13.95	2.24	0.717	22.41644
CH13	On Floor 2 - RHS near door	22.92	Wall 2 @ 2.9	1.8	3.51	0.717	4.527183
CH14	On Floor 3 - LHS near door	21.63	Wall 2 @ 2m	12.85	2.77	0.717	25.52594
CH15	On Floor 4 - RHS near window	21.71	Wall 2 averag	13.95	2.87	0.717	28.66974
CH16 - Ch0	Wall 1 (RHS) inside surface at 2.9m	24.24	Wall 3 @ 2.9	1.8	2.28	0.717	2.93914
CH17 - Ch1	Wall 1 inside surface at 2m	23.52	Wall 3 @ 2m	12.85	2.22	0.717	20.41535
CH18 - Ch2	Wall 1 outside surface at 2.9m	24.80	Wall 3 averag	13.95	2.22	0.717	22.24296
CH19 - Ch3	Wall 1 outside surface at 2m	26.01	Wall 4 @ 1m	4.05	-0.48	0.402	-0.78702
CH20 - Ch4	Wall 1 External Ambient at 2m	26.78	Wall 4 @ 2m	5.148	0.38	8.54	16.82994
CH21 - Ch5	Wall 2 (Door side) inside surface at 2.	23.77	Wall 4 @ 2.5	4.752	2.07	0.402	3.94933
CH22 - Ch6	Wall 2 inside surface at 2m	23.67	Wall 4 averag	13.95	0.71	3.66	36.004
CH23 - Ch7	Wall 2 outside surface at 2.9m	27.27	Beam 1		3.59	0.018333	275.1765
CH24 - Ch8	Wall 2 outside surface at 2m	26.44	Beam 2		3.41	0.018333	261.182
CH25 - Ch9	Wall 2 External Ambient at 2m	26.80	Beam 3		3.50	0.018333	267.8425
CH26 - Ch10	Wall 3 (LHS) inside surface at 2.9m	23.43	Air		4.77		
CH27 - Ch11	Wall 3 inside surface at 2m	23.19					
CH28 - Ch12	Wall 3 outside surface at 2.9m	25.70					
CH29 - Ch13	Wall 3 outside surface at 2m	25.41					
CH30 - Ch14	Wall 3 External Ambient at 2m	25.90					
CH31 - Ch15	Wall 4 (Window side) inside surface a	23.73					
CH32 - Ch0	Wall 4 inside surface at 2m (glass)	24.01					
CH33 - Ch1	Wall 4 inside surface at 2.5m	23.24					
CH34 - Ch2	Wall 4 outside surface at 1m	24.89					
CH35 - Ch3	Wall 4 outside surface at 2m (glass)	24.39					

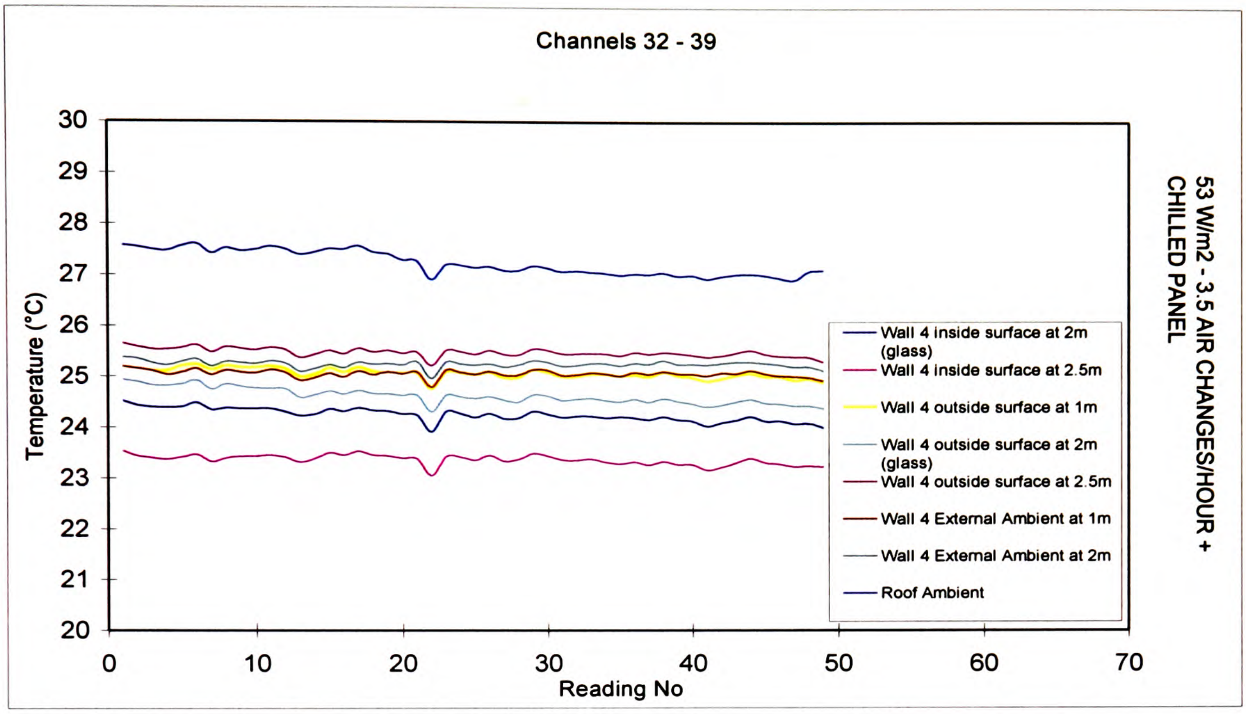
CH36 - Ch4	Wall 4 outside surface at 2.5m	25.31					
CH37 - Ch5	Wall 4 External Ambient at 1m	24.94		Heat load			1073
CH38 - Ch6	Wall 4 External Ambient at 2m	25.14					
CH39 - Ch7	Roof Ambient 1	27.11		Cooling due to air system			304.0402
CH40 - Ch8	Under Floor 1 - LHS near window	21.12					
CH41 - Ch9	Under Floor 2 - RHS near door	21.13		Cooling due to water system			804.201
CH42 - Ch10	Under Floor 3 - LHS near door	21.15					
CH43 - Ch11	Under Floor 4 - RHS near window	21.21		Overall heat flux from facility			161.4194
CH44 - Ch12	Ceiling 4 - RHS near window	21.12					
CH45 - Ch13	Under Roof 1 - Near window	23.71		Energy Balance			126.1783
CH46 - Ch14	Under Roof 2 - Near door	24.32					
CH47 - Ch15	Roof Ambient 2	26.50					
CH48 - Ch0	Column 1 at 0.01 m	21.25		21.31006	0.01		
CH49 - Ch1	Column 1 at 0.1 m	21.43		21.30859	0.1		
CH50 - Ch2	Column 1 at 0.6 m	22.31		22.15332	0.6		
CH51 - Ch3	Column 1 at 1.1 m	23.27		23.17529	1.1		
CH52 - Ch4	Column 1 at 1.7 m	23.56		23.37109	1.7		
CH53 - Ch5	Column 1 at 2.1 m	23.66		23.41016	2.1		
CH54 - Ch6	Column 1 at 2.6 m	23.76		23.68164	2.6		
CH55 - Ch7	Column 1 at 2.69 m	23.82		23.77197	2.69		
CH56 - Ch8	Column 2 at 0.01 m	21.37					
CH57 - Ch9	Column 2 at 0.1 m	21.19					
CH58 - Ch10	Column 2 at 0.6 m	21.99		Air flow rat	0.053	m^3/s	
CH59 - Ch11	Column 2 at 1.1 m	23.08		Water flo	5.50E-02	m^3/s	
CH60 - Ch12	Column 2 at 1.7 m	23.19		Air Cp	1010	J/kgK	
CH61 - Ch13	Column 2 at 2.1 m	23.16		Water Cp	4180	J/kgK	
CH62 - Ch14	Column 2 at 2.6 m	23.60		Air density	1.19	kg/m^3	
CH63 - Ch15	Column 2 at 2.69 m	23.73		Water Den	1000	kg/m^3	
CH64 - Ch0 (PRT)	Beam 1 Supply	14.61					
CH65 - Ch1 (PRT)	Beam 2 Supply	14.55					
CH66 - Ch2 (PRT)	Beam 3 Supply	19.18					
CH67 - Ch3 (PRT)	Beam 1 Return	18.20					
CH68 - Ch4 (PRT)	Beam 2 Return	17.96					
CH69 - Ch5 (PRT)	Beam 3 Return	18.07					

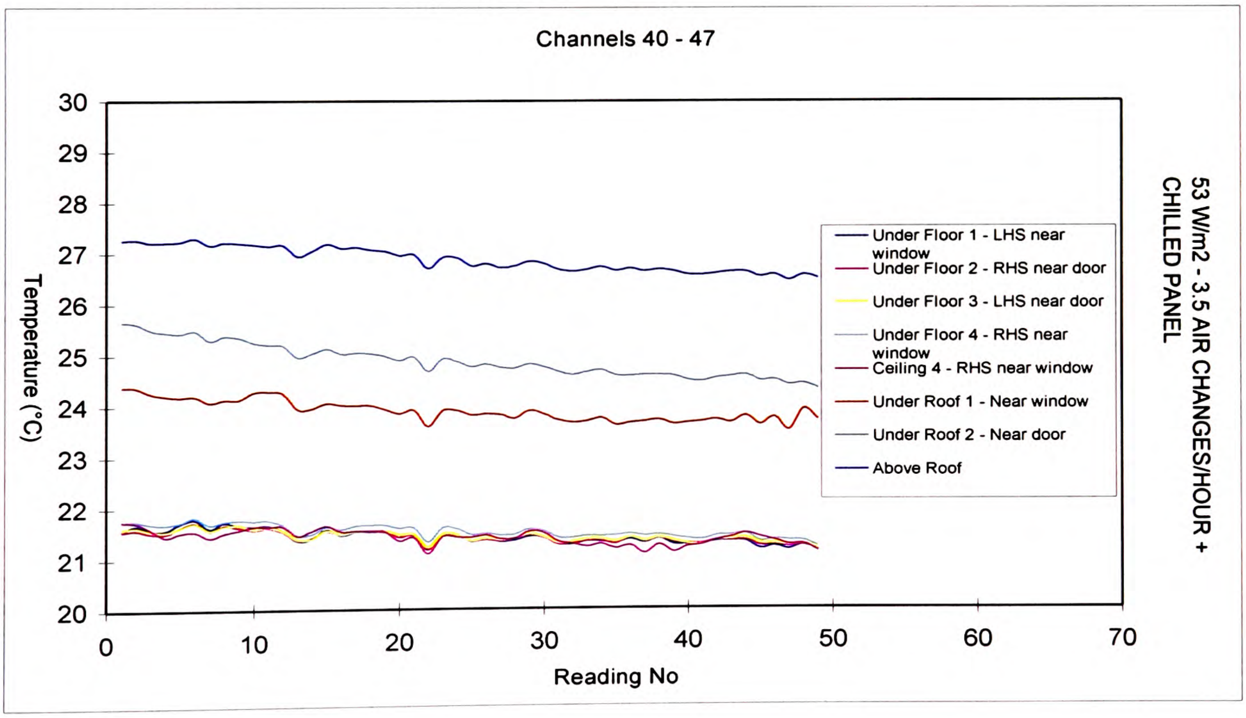

Channels 0 - 7
Temperature (°C)
Reading No
53 W/m2 - 3.5 AIR CHANGES/HOUR + CHILLED PANEL
Air Supply 1 - LHS
Air Supply 2 - RHS
Air Supply 3 - Control Point
Extract 1 - Near window
Extract 2 - Near door
Globe 1 - Pole 1
Globe 2 - Pole 1
Globe 1 - Pole 2

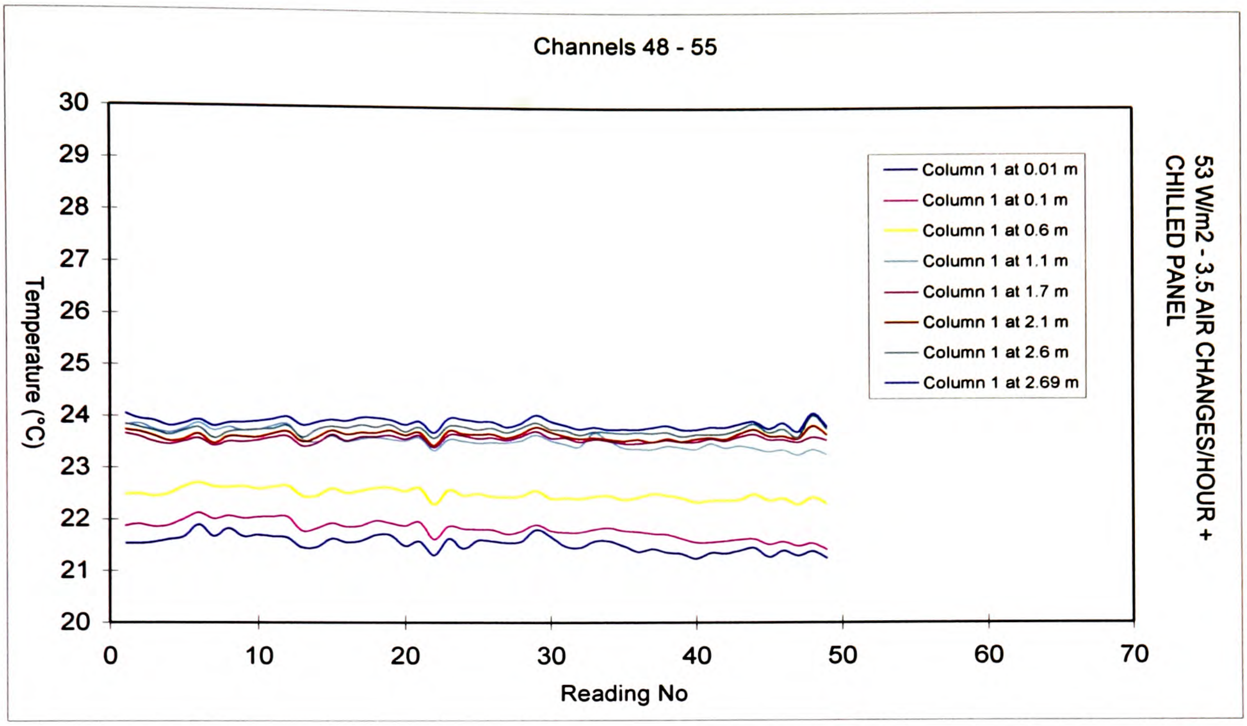

Channels 8 - 15
Temperature (°C)
Reading No
53 W/m2 - 3.5 AIR CHANGES/HOUR + CHILLED PANEL
Globe 2 - Pole 2
Ceiling 1 - LHS near window
Ceiling 2 - RHS near door
Ceiling 3 - LHS near door
On Floor 1 - LHS near window
On Floor 2 - RHS near door
On Floor 3 - LHS near door
On Floor 4 - RHS near window

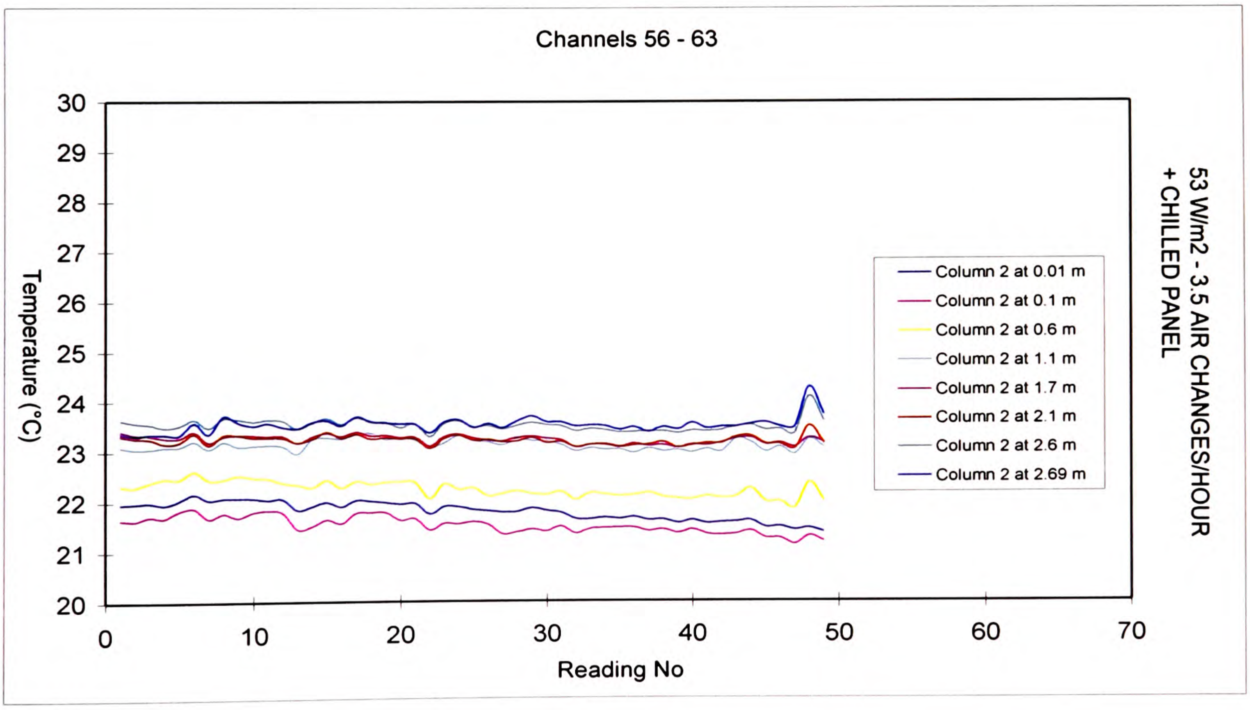

Channels 16 - 23
Temperature (°C)
30
29
28
27
26
25
24
23
22
21
20
0
10
20
30
40
50
60
70
Reading No
Wall 1 (RHS) inside surface at 1m
Wall 1 inside surface at 2m
Wall 1 outside surface at 1m
Wall 1 outside surface at 2m
Wall 1 External Ambient at 2m
Wall 2 (Door side) inside surface at 1m
Wall 2 inside surface at 2m
Wall 2 outside surface at 1m
53 W/m2 - 3.5 AIR CHANGES/HOUR + CHILLED PANEL

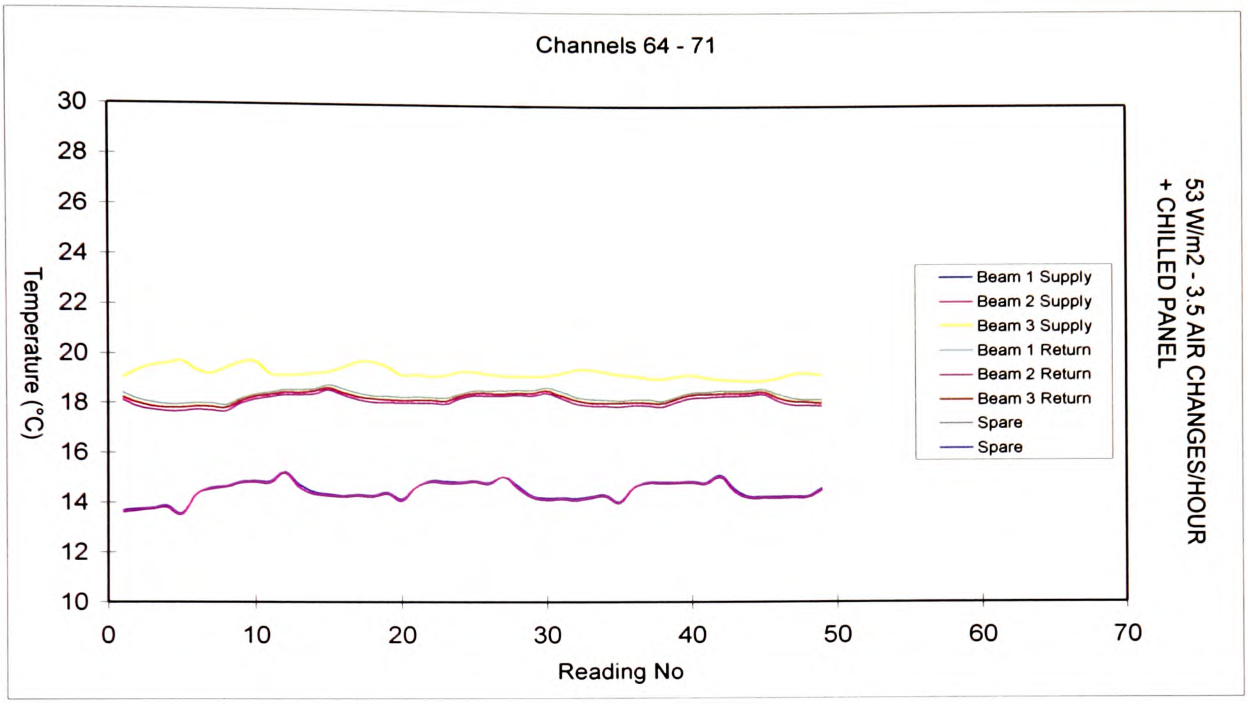

Channels 24 - 31
Temperature (°C)
30
29
28
27
26
25
24
23
22
21
20
0
10
20
30
40
50
60
70
Reading No
Wall 2 outside surface at 2m
Wall 2 External Ambient at 2m
Wall 3 (LHS) inside surface at 1m
Wall 3 inside surface at 2m
Wall 3 outside surface at 1m
Wall 3 outside surface at 2m
Wall 3 External Ambient at 2m
Wall 4 (Window side) inside surface at 1m
53 W/m2 - 3.5 AIR CHANGES/HOUR + CHILLED PANEL


Channels 32 - 39
Temperature (°C)
30
29
28
27
26
25
24
23
22
21
20
0
10
20
30
40
50
60
70
Reading No
Wall 4 inside surface at 2m (glass)
Wall 4 inside surface at 2.5m
Wall 4 outside surface at 1m
Wall 4 outside surface at 2m (glass)
Wall 4 outside surface at 2.5m
Wall 4 External Ambient at 1m
Wall 4 External Ambient at 2m
Roof Ambient
53 W/m2 - 3.5 AIR CHANGES/HOUR + CHILLED PANEL


Channels 40 - 47
Temperature (°C)
30
29
28
27
26
25
24
23
22
21
20
0
10
20
30
40
50
60
70
Reading No
Under Floor 1 - LHS near window
Under Floor 2 - RHS near door
Under Floor 3 - LHS near door
Under Floor 4 - RHS near window
Ceiling 4 - RHS near window
Under Roof 1 - Near window
Under Roof 2 - Near door
Above Roof
53 W/m2 - 3.5 AIR CHANGES/HOUR + CHILLED PANEL


Channels 48 - 55
Temperature (°C)
Reading No
Column 1 at 0.01 m
Column 1 at 0.1 m
Column 1 at 0.6 m
Column 1 at 1.1 m
Column 1 at 1.7 m
Column 1 at 2.1 m
Column 1 at 2.6 m
Column 1 at 2.69 m
53 W/m2 - 3.5 AIR CHANGES/HOUR + CHILLED PANEL


Channels 56 - 63
Temperature (°C)
Reading No
Column 2 at 0.01 m
Column 2 at 0.1 m
Column 2 at 0.6 m
Column 2 at 1.1 m
Column 2 at 1.7 m
Column 2 at 2.1 m
Column 2 at 2.6 m
Column 2 at 2.69 m
53 W/m2 - 3.5 AIR CHANGES/HOUR + CHILLED PANEL



Channels 64 - 71
30
28
26
24
22
20
18
16
14
12
10
Temperature (°C)
0
10
20
30
40
50
60
70
Reading No
Beam 1 Supply
Beam 2 Supply
Beam 3 Supply
Beam 1 Return
Beam 2 Return
Beam 3 Return
Spare
Spare
53 W/m2 - 3.5 AIR CHANGES/HOUR + CHILLED PANEL

APPENDIX III

TRANSFER REPORT

CONTENTS

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Introduction	1
Feasibility study	3
Future work	5

INTRODUCTION

The purpose of this report is to demonstrate progress to date, and identify a subsequent programme of work to provide a suitable basis for work at PhD standard that can be pursued to completion.

Aims and Objectives

The aim of the study has been to demonstrate a wider application for the use of displacement ventilation in commercial buildings in order to achieve better air quality in the workplace with lower energy consumption.

The objectives are to clarify the areas of uncertainty in respect of:

* air distribution patterns
* air quality
* suitability of building types
* energy requirements
* ability to deal with high heat gains.

Literature Review

My literature review has been two pronged. Firstly I have made use of the database search facilities in the Learning Resources Centre. The primary sources of useful information being ISBEDEX and BRIX, secondly, through my collaborating organisation l was able to identify and contact current researchers to discuss work in progress and as yet unpublished.

Three broad categories of research have been identified:

* to develop underlying theory with the aim of providing guidance for designers

* to establish the limitations of application

* to investigate the merit of combining displacement ventilation with static cooling to bring offices with high heat loads the benefits of displacement ventilation without overheating problems.

With respect to the latter category, a number of researchers have suggested that downward convection due to cold surfaces such as windows or cold external walls will seriously disrupt the buoyancy driven displacement flow. This is considered a sufficient disturbance to break down the stratification boundary, mixing air from the contaminated upper zone with clean air from the lower zone, negating the main benefit of displacement ventilation.

It seemed likely that the deliberate introduction of cold surfaces as static cooling devices would result in the same detrimental effect. I was able to demonstrate that this was the case during my preliminary work at BSRIA, which is described below.

As part of my activities in identifying current research I visited the Building Services Research and Information Association (BSRIA), and as a result of the visit was invited to work with them in this area of research.

A successful University Funding of Research (UNIR) bid in the summer of 1994 allowed me to work virtually full time at BSRIA from October 1994 to January 1995.

The benefits of this were:-

* accelerated progress due to full-time working
* training in relevant measurement techniques
* working with experienced researchers, with resulting synergy.

To familiarise myself with the test rig and associated instrumentation, I joined the team towards the end of a test programme investigating the relative merits of ceiling mounted chilled beams and chilled panels used in conjunction with displacement ventilation. Before the rig was dismantled I was able to conduct some smoke tests to show the disruptive effect that the chilled ceilings were producing to the detriment of good air quality.

I then proceeded with a number of tests exploring the problem of dealing with high heat gains. The basis of my hypothesis was that it should be possible to introduce a higher air change rate to deal with higher heat loads, without causing occupant discomfort. My tests were carried out using the standard type of displacement diffuser as traditionally used in industrial applications. My early results indicated that modest improvements could be achieved. Whilst discussing some of the problems that I was experiencing with one of the research engineers at BSRIA, he suggested trying a completely different type of diffuser, one that he had used in solving a ventilation problem in submarines! Subsequently the theory that I had suggested combined with the knowledge another researcher had of a material used on an earlier unrelated project led to a proposal for a feasibility study to be carried out.

Feasibility Study

The study was to establish:

i) whether a textile diffuser could be used as a low level supply device to achieve a displacement effect in a room

ii) whether a significant increase in air supply rate could be achieved without producing unacceptably high velocities in the occupied space

iii) whether the increase in air supply rate produced a satisfactory temperature regime in the occupied space to eliminate the need for supplementary cooling in typical commercial office situations.

Diffusers were designed and manufactured to suit the layout of the test room at BSRIA and with a heat load of $50W/m^2$ and an air change rate of 9.3 per hour, (maximum setting of air handling unit available), tests were carried out.

Measurements of air speed and temperature were recorded on a regular grid of points marked on the floor of the test room at 600mm centres. At each node of the sampling grid, the parameters were measured at regular heights, i.e. h/12, 3h/12, 5h/12, 7h/12, 9h/12, 11h/12. After measurements had been recorded, the instrument column was moved to the next position and left for 3 minutes for conditions in the room to recover from the disruption caused in moving the column.

The results from this test were compared with earlier tests from the same room using standard bin diffusers when the heat load was $40W/m^2$ and the air change rate 3.5 per hour.

Despite the slightly higher load the average air temperatures in the room were significantly lower using the fabric diffusers with the higher air change rate, whilst the resultant air speeds were very similar to those produced by the bin diffusers with the lower air change rate. I had predicted that the air temperatures would be lower, but not by such a large factor, (typically six degrees K).

It has been demonstrated therefore that higher air change rates can be applied to combat overheating without causing draught discomfort, using a fabric diffuser. Further investigation is clearly warranted.

The findings of my literature review and this feasibility study are the subject of a paper "Displacement Ventilation Applications in Commercial Offices - an Overview" that is being submitted to the Building Services Engineering Research and Technology (BSERT) Journal for publication. This quarterly journal is the leading research publication for this area of work and has international standing.

Future Work

The final conclusion in the paper above presents the hypothesis that the number of applications for displacement ventilation, without resorting to any other form of supplementary cooling, could significantly increase if increased air volumes can successfully be delivered using textile diffusers.

The testing of this hypothesis and its practical and commercial application form the basis for the proposal for PhD study.

Proposed programme

Data Collection and Analysis

It is intended to operate diffusers for a range of heat loads at different air supply rates and analyse the following:

* resulting temperature and velocity profiles,
* resulting air quality using tracer gas techniques,
* performance of diffuser in respect of room air diffusion patterns.

The procedure for each test will include detailed measurements and observations of air movement using smoke injected into the supply air. A multi-channel flow analyser with 12 probes will be used to measure environmental conditions in the test chamber. Air temperatures and surface temperatures in and around the test chamber will be measured using T-type thermocouple junctions connected to an Anville Instruments Scan 1000 data logger.

The data collection process would be carried out at the test facilities of BSRIA as part of their ongoing project to develop a Code of Practice for Displacement Ventilation. The analysis will take place partly using the facilities of BSRIA and partly using the computing facilities of the University of Glamorgan.

It is anticipated that this work could be completed by the summer of 1996.

This will be followed by a period of writing up which will include an evaluation of the contribution made, the limitations of the work, and its future potential applications. Conclusions will aim to produce future recommendations.

It is anticipated that this work will take a further 12 months. In light of current findings it is proposed to modify the title to accommodate the hypothesis developed, as follows:

> "A study of the use of textile diffusers to optimise the benefits of displacement ventilation".

APPENDIX IV

PUBLICATIONS

Refereed Conference Publication

1. Geens A. J., Graham M. S., Alamdari F., "Displacement Ventilation applications – an alternative view" CIBSE National Conference, 1997, Vol. 1, pp 38-44.

Invited Conference Publication

1. Geens A. J., Alamdari F., " Displacement Ventilation applications in commercial offices", 2nd International Conference, Vilnius University, 1996.

DISPLACEMENT VENTILATION APPLICATIONS - AN ALTERNATIVE VIEW

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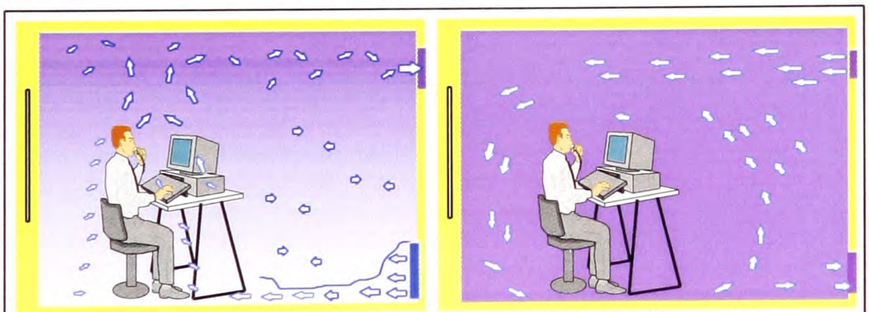
This paper critically reviews current and previous research into the use of displacement ventilation in commercial offices with and without supplementary static cooling devices. It also reports the findings of a preliminary study of a displacement ventilation technique that may increase the scope of application for displacement ventilation systems without the need for supplementary static cooling.

1. Introduction

Buoyancy driven displacement ventilation involves the introduction of fresh air into a space at low level, at a temperature slightly lower than the room air temperature (Fig.1). The cooler air tends to spread across the floor until local heat sources cause convective plumes to rise. Claims that displacement ventilation provides better air quality in the breathing zone, with a reduced energy requirement when compared with a mixed dilution ventilation system are well documented.[1][2][3] A displacement system can achieve a high ventilation effectiveness when the internal sources produce both heat and contaminants, as is the case with people and some office equipment. The benefits available if these principles can be delivered in practice, are improved indoor air quality and also lower energy consumption due to lower flow rates and more free cooling, with supply temperature typically 19-21^{o}C. The vertical temperature gradient produced by displacement flow, results in higher temperatures at ceiling level than with a dilution or "mixing" system. The main limitation of displacement ventilation in offices is the inability to remove high internal heat loads while maintaining an acceptable temperature gradient within the occupied zone.



Displacement ventilation (DV) Mixing ventilation (MV)

Fig.1. The Principle of Displacement Ventilation

In the belief that a better understanding of the mechanisms of displacement ventilation will reduce the level of uncertainty in the design of such systems, a wide range of research activity is being undertaken across Europe and in the Far East. This paper describes developments to date, and identifies areas where further research may be required. Three broad categories of research have been identified:

- to develop underlying theory with the aim of providing guidance for designers
- to establish the limitations of application, and the effects of cold surfaces and obstructions on displacement ventilation
- to investigate the merit of combining displacement ventilation with static cooling systems to bring offices with high cooling loads the benefits of displacement ventilation without overheating problems.

2 DEVELOPMENT OF UNDERLYING THEORY

The approach to this area of work is varied. Some teams have concentrated their activity in one field of the model shown in Fig. 2, whereas some have worked holistically towards offering design advice. Single focus research has contributed some useful findings as described below:

Sandberg[4] has investigated the effect of movement of a heat source within the space, (i.e. a person walking across the office), and concluded that movement lowers the stratification height and causes oscillations of the interface. This was predicted by mathematical modelling, and confirmed by conducting tests on a scale model.

This work identifies a possible problem although a view is put forward by Wyatt[5] that a thin "personalised" boundary layer of fresh air is maintained in the breathing zone despite the lowering of the interface.

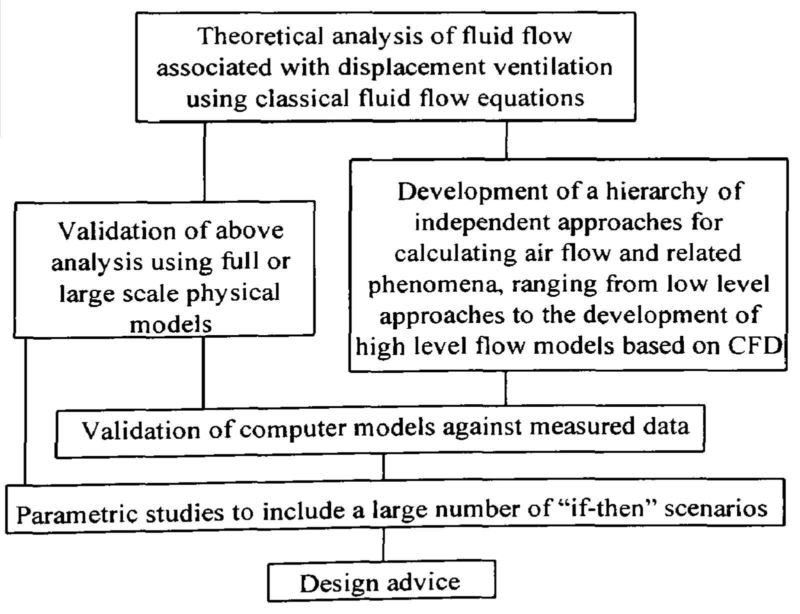


Fig.2. Research Model

Examples of the "total concept" approach to research generally include the verification of a CFD package as a design aid.

Alamdari[2] has used a combination of site measurements and computer modelling to confirm the variation of room air temperature with height for displacement ventilation systems. Confidence is expressed in the CFD modelling to investigate further the problems of floor level obstructions and down flow from cold surfaces.

As the air velocities in the test room experimental work were too low to measure, Holmberg[6] turned to computer modelling to demonstrate that a horizontal displacement effect could be achieved without help from thermal forces. A similar conclusion was made by Alamdari[2].

3 LIMITATIONS OF APPLICATION

A number of claims are made about the amount of cooling that can be handled by a displacement ventilation system. Values of 70 - 100 W/m^2, M Koganei[7] 40 - 50 W/m^2 C Twinn[8] are examples that show that there are conflicting views. This may be the reason that designers are looking for additional cooling via "static" devices.

There are also conflicting claims over the real air quality benefits associated with displacement ventilation. Cox[9] measured a ventilation effectiveness of 1 in a test room, no better apparently than a good dilution system. Guntermann[10] identified an improved air quality at a height of 1 - 1.4 m near heat sources. Lauriken[11] states that with displacement ventilation, air quality may be 3 times better than with a dilution system with the same air flow rate. Breun[12] links relative improved air quality with increasing air charge rates when comparing displacement with dilution systems.

Although the findings of all four researchers may be accurate and correct, the apparent conflict may simply be due to the fact that they are reporting on different situations, Sateri[13] identifies the need to measure air quality in the breathing zone. With a mixing system (assuming perfect mixing), the measurement of contaminants can be taken anywhere in the room to calculate ventilation effectiveness, whereas with a displacement system the level of contaminant is very variable with location in the room, and if the effectiveness is to reflect the experience of the occupant, it is only the breathing zone that is relevant.

4 PREVIOUS WORK ON DISPLACEMENT WITH STATIC COOLING

A number of researchers[1][2][7] have suggested that downward convection due to cold surfaces such as windows or cold external walls will seriously disrupt the buoyancy driven displacement flow. This is considered a sufficient disturbance to break down the stratification boundary, mixing air from the contaminated upper zone with the clean lower zone, negating the main benefit of the displacement system.

Krohne[14] has concluded that displacement ventilation in combination with cooled ceilings, does not always have an advantage over mixing ventilation where air quality is concerned, but that thermal comfort conditions are achieved. Recent physical tests carried out at BSRIA support this finding. Using a model room facility incorporating a displacement ventilation system with a chilled panel ceiling, smoke visualisation tests were carried out, releasing test smoke above the false ceiling. It was observed that the room rapidly became contaminated by the smoke. On inspection, it was evident that smoke was falling through every extract grille and unsealed joint in the ceiling. This indicates that air in the ceiling void is being cooled by the reverse side of the chilled panels, and there is insufficient pressure difference between the room and ceiling void to overcome the resulting negative buoyancy.

Although this re-circulation effect enhances the heat exchange from the chilled panel, it is destroying the air quality characteristic of the displacement ventilation system. The work at BSRIA concludes that where static cooling devices are used in conjunction with displacement ventilation systems, care should be exercised in the specification and construction of the ceiling, (i.e. sealed joints), to ensure positive air flow from room to ceiling void.[15] Further, in the case of chilled panels, the insulation on the back of the panel within the ceiling void must be in place.

Additionally, work carried out by Taki(16) indicates that the temperature of the chilled water is influencing the displacement flow increasingly as it reduces from 21°C, and that with a ceiling temperature of 14°C, displacement flow is completely destroyed.

Despite this concern, there is significant research activity into the use of static cooling with displacement ventilation to counter the risk of thermal discomfort due to high heat gains, and also considerable commercial exploitation of the technique.[2][5][17][18] This activity seems to be driven by the over-riding need to reduce design risk of overheating which is easily perceived by the building occupants at the expense of air quality which is less tangible. This could arguably be overlooking current design philosophy in two major respects in addition to the air quality concerns. The positioning of static cooling at ceiling height introduces a false or lowered ceiling with the following consequences:

- the creation of a barrier to building fabric thermal storage by the ceiling slab.
- the depression of the high temperature zone towards the occupied zone.

An alternative method of applying static cooling to the displacement ventilation system is proposed by Ma[19], who suggests supplying chilled water to the heating system radiators. This will provide some cooling effect without the disadvantages identified above, and as the radiators are located low in the pool of clean air, their downward convection should not significantly reduce air quality and may in fact assist the displacement flow. This system also has cost benefits over a chilled ceiling, but further work is required as there is little information of the cooling performance of radiators, or the ratio of radiant to convective output.

5 RECENT WORK

One element of the recent work at BSRIA has been to establish the limitations of displacement ventilation in dealing with heat loads. It has been recognised that the primary limitation is the amount of air that can be provided through conventional wall or floor mounted displacement diffusers without causing discomfort due to draughts. Preliminary studies carried out at BSRIA using fabric diffusers indicate that it may be possible to deal with higher heat loads without causing draughts(20). Studies investigating the interaction of chilled ceilings with semi-cylindrical wall mounted displacement diffusers had already been carried out in a test room measuring 10m x 6m with a floor to ceiling height of 2.7m, as shown in Fig.3. Although it proved difficult to match the room heat load exactly, the results from these studies would provide the reference for the tests with the fabric diffusers, with respect to their ability to limit the temperature rise in the room.

Air speed and air temperature measurements in the space were carried out using two arrays of six Dantech 54R10 probes incorporating spherical omni-directional hot film anemometers and thermistors. The probes were mounted on mobile stands, which could then be positioned on the grid points in the test room. The 4 semi-cylindrical diffusers were replaced by 2 polyester/cotton fabric diffusers, installed in 10m lengths on opposite

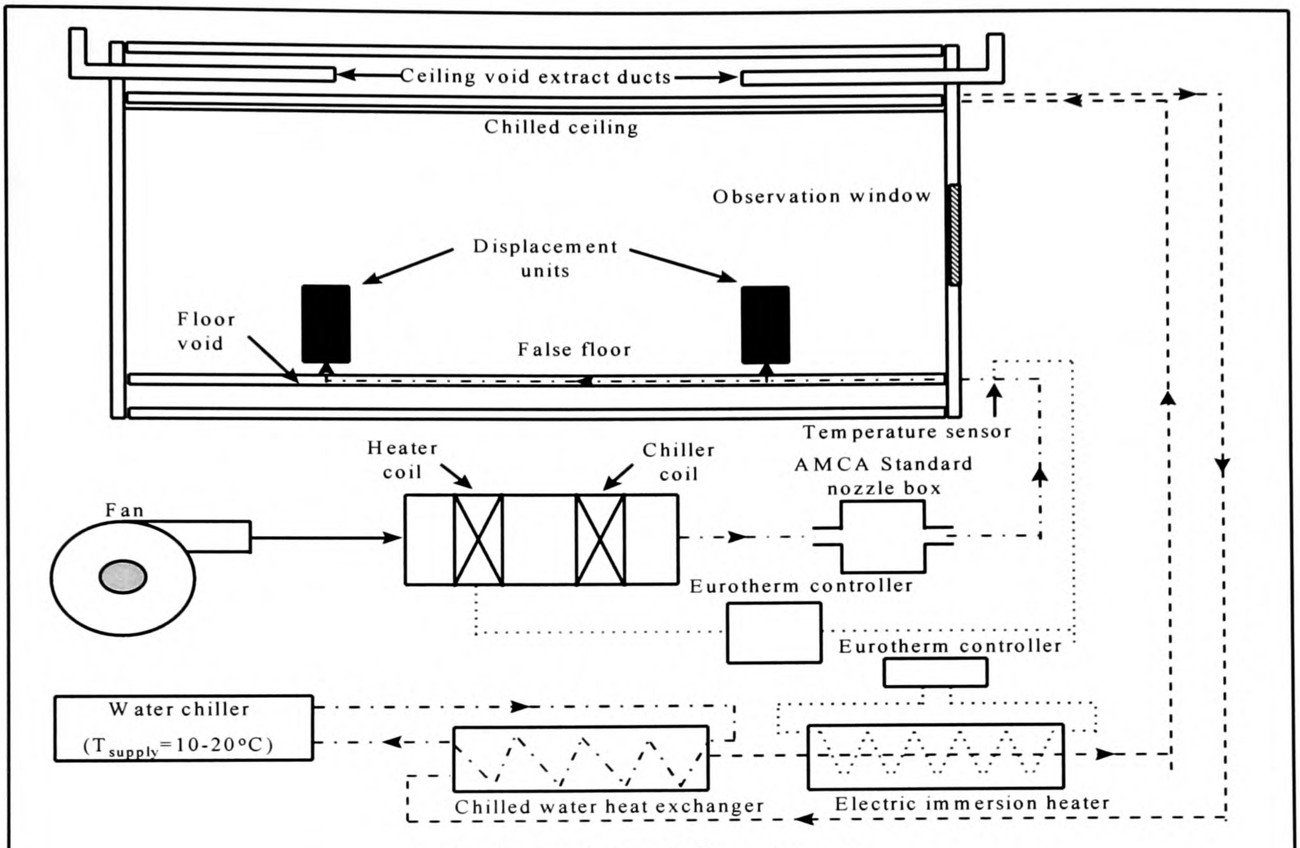


Fig.3. Original Test Room

walls of the room. These diffusers, normally used in the food preparation industry, were custom made in a "D" section for this experiment.
With a heat load of 50W/m^2 provided by PCs, 100W heaters simulating people, and a photocopier, arranged as shown in Fig. 4, and an air change rate of 9.3 per hour, the maximum output of the fan, conditions were monitored in the test room. These were compared with earlier results from the same room using standard semi-cylindrical metal diffusers when the heat load was 40 W/m^2 and the air change rate 3.5 per hour.

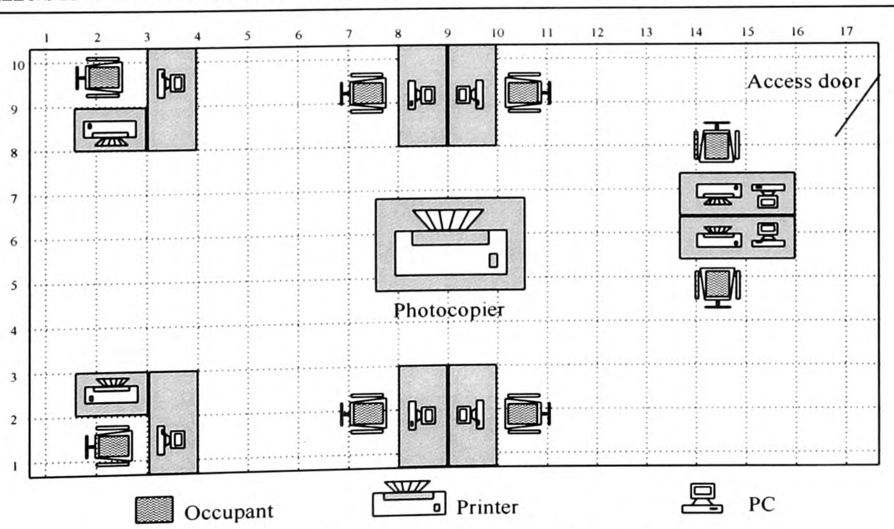


Fig.4. Floor plan of original test room showing test grid points

Fig. 5 shows that despite the slightly higher load the average air temperatures in the room were significantly lower using the fabric diffusers with the higher air change rate, as would be expected. However, Fig 6 shows that the average velocities produced by the fabric diffusers were very similar to those produced by the bin diffusers. Encouraged by these preliminary findings, further tests were carried out to directly compare the performance of the fabric diffuser with and without a chilled ceiling panel.

Fig.5.

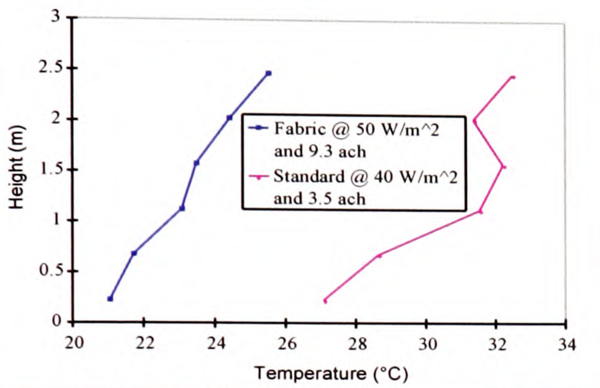
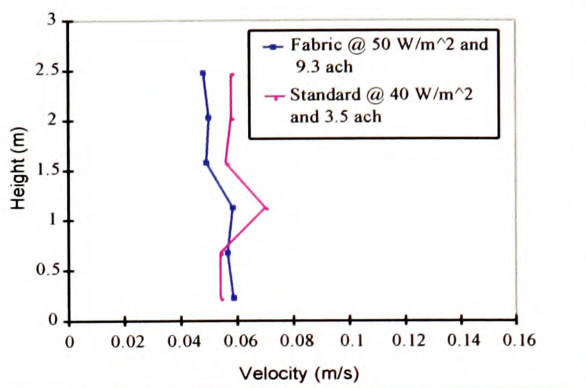


Fig.6.



A number of shortcomings were identified with the original test room, the most significant being the difficulties in maintaining steady state conditions for the length of time involved in logging the conditions. As these shortcomings reduced confidence in the results, the experiment was repeated under more controlled conditions. A smaller test room 4.5m x 4.5m was constructed within the original room, resulting in a reduction in measuring time, and giving more stable conditions around the room. The modified arrangement is shown in Figs 7 and 8.

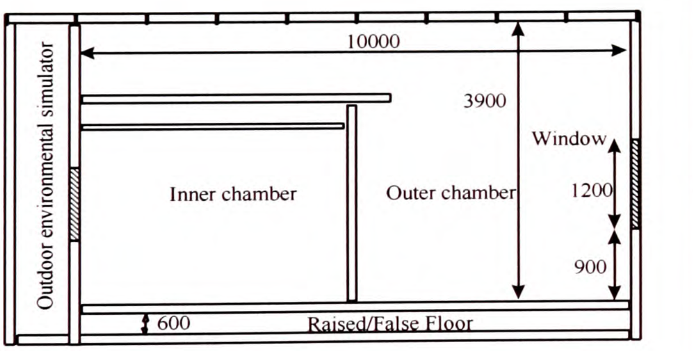


Fig.7. Modified Test Room

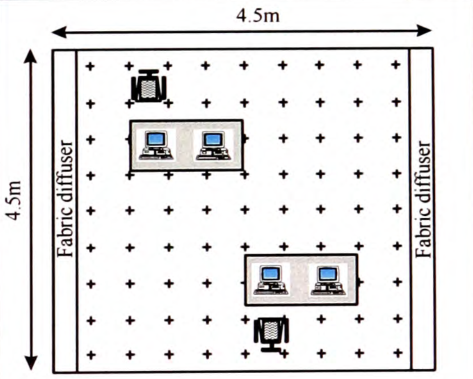
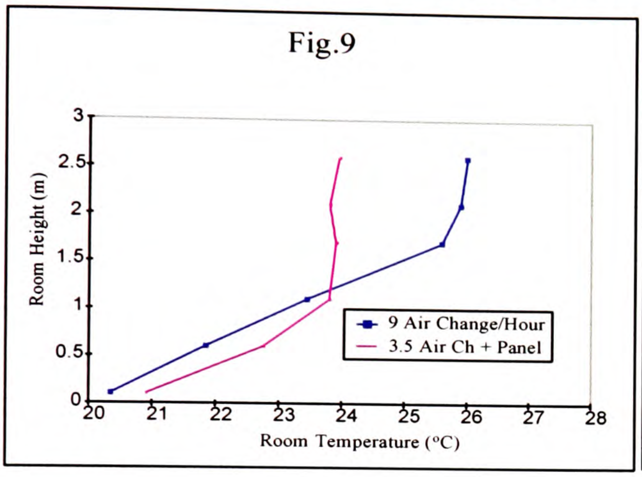
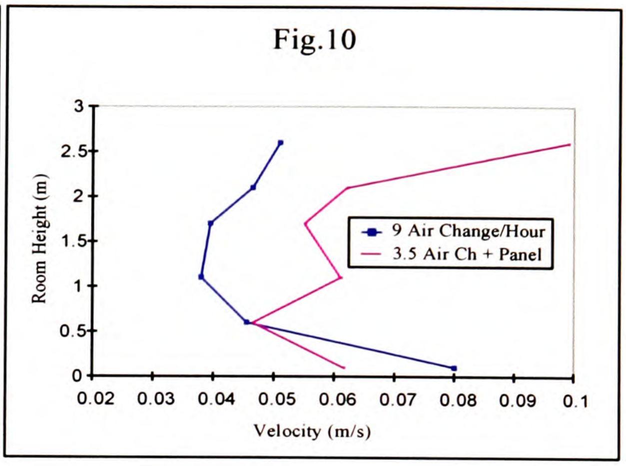


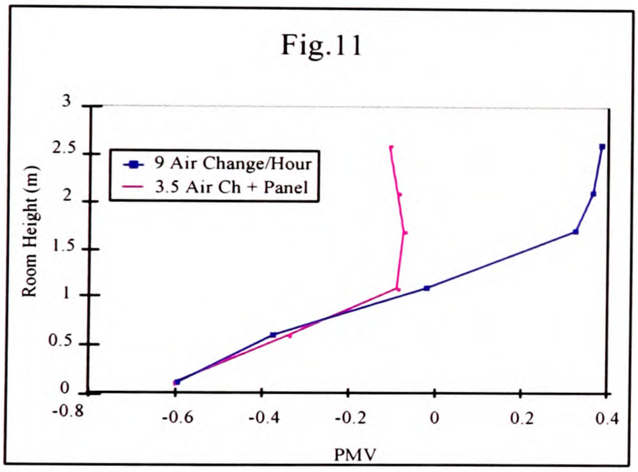
Fig.8. Modified Floor Plan

With a room load of approximately 60 W/m^2 , (57 W/m^2), the performance of the fabric diffuser supplying 3,6, and 9 air changes/hour was compared with the performance of the fabric diffuser supplying 3.5 air changes/hour assisted by a chilled ceiling panel. With the panel operating, the water supply temperature was 14.5^{o}C, providing 950W of cooling, and the ventilation air, 200W. The load and panel assisted air supply rate were selected to match tests already conducted as part of the BSRIA Code of Practice programme, and the maximum air change rate for displacement ventilation only was selected close to the rate that had been successfully established in the previous test facility. Only the results at 9 air changes have been shown for clarity. Temperature, velocity, PPD and PMV are used as performance indicators. ISO 7730(21) recommends the following:

* vertical temperature gradient of 3K from ankle to head (approx 3K/m seated)
* velocity less than 0.15 m/s in winter, 0.25 m/s in summer
* PPD less than 10
* PMV between -0.5 and +0.5







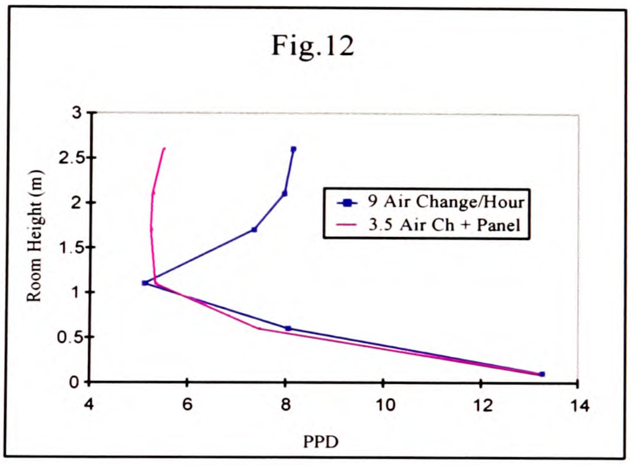


Fig. 9 shows that the fabric diffuser at 9 air changes produces a uniform temperature gradient to a height of 1.7m, indicating a good displacement flow to this height. For seated occupants, the temperature gradient is acceptable. It is possible that without the suspended ceiling, this situation would be improved as the maximum temperature would be reduced. Fig 10 indicates that there are no velocity problems when using the fabric diffusers at 9 air changes per hour. Figs 11 and 12 indicate that acceptable PMV and PPD limits are exceeded at low level with the fabric diffusers. This is where velocities are known to be highest and the temperatures are lowest. Adopting the same measurement grid configuration as for the standard semi-cylindrical metal diffusers, 18 low-level readings were taken with the probes actually pushed into the fabric diffusers. If these readings were to be excluded from the analysis, the fabric diffusers could be expected to provide better comfort conditions.

6 CONCLUSIONS

In the field of research into Displacement Ventilation examples have been found of contradictory research findings. This can be explained at least in part, because the objectives, the parameters considered, and the assumptions made, were different. There appears to be some merit in attempting to standardise this. For example, when establishing the ventilation effectiveness of displacement systems, a standard measuring point for level of contaminant should be stated.

Particular problems that require further research to reduce the design risk in applying displacement ventilation systems more widely are:

i) environmental performance assessment and comparison of displacement ventilation with chilled ceiling devices and displacement ventilation with low level wall mounted systems (such as radiators).

ii) consistency of input data for CFD analysis, particularly in representation of air terminal devices, heat sources, moving objects and also in appropriate mathematical modelling of radiation heat transfer.

iii) the problem of dealing with higher cooling loads, without resorting to static cooling with the associated problems identified in 4 above, should be addressed. The findings described in 5 above present the hypothesis that the number of applications for displacement ventilation without static cooling could be increased if larger air volumes could be supplied without causing draughts at low level, or causing noise problems. Additionally, given the higher ventilation efficiency, it is likely to be advantageous to use fabric diffusers where contaminant control rather than temperature control is the over-riding factor, such as where smoker/non-smoker segregation is an issue. Comfort limits in terms of velocity are not challenged at all with these diffusers at 9 air changes per hour. These preliminary tests with a fabric diffuser are very promising and further physical tests and CFD modelling are proposed.

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DISPLACEMENT VENTILATION APPLICATIONS IN COMMERCIAL OFFICES - AN OVERVIEW

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Abstract

This paper critically reviews current and previous research into the use of displacement ventilation in commercial offices with and without supplementary cooling devices. It also reports the findings of a preliminary study of a displacement ventilation technique that may increase the scope of application for displacement ventilation systems without the need for supplementary cooling.

1. Introduction

Claims that displacement ventilation provides better air quality in the breathing zone, with a reduced energy requirement when compared with a mixed dilution ventilation system are well documented.[1][2][3]

A displacement system can achieve a high ventilation effectiveness when the internal sources produce both heat and contaminants, as is the case with people and some office equipment. The vertical temperature gradient suggests that clean and contaminated air are separated, with contaminants collecting above the occupied zone, where they are easily extracted.

In the belief that a better understanding of the mechanisms of displacement ventilation will reduce the level of uncertainty in the design of such systems, a wide range of research activity is being undertaken across Europe and in the Far East.

Additionally, research in other areas is highlighting the limitations of currently adopted comfort criteria in particular situations, and in fact modifications to these are suggested.[4][5][6] These new concepts need developing as they will certainly prove relevant when considering the suitability of displacement ventilation for a range of applications. A particular drawback with current comfort criteria is that it makes no allowance for the desirability of short-term transient conditions.

This paper describes developments to date, and identifies areas where further research may be required.

Three broad categories of research have been identified:

- to develop underlying theory with the aim of providing guidance for designers
- to establish the limitations of application

- to investigate the merit of combining displacement ventilation with static cooling to bring offices with high cooling loads the benefits of displacement ventilation without overheating problems.

2 DEVELOPMENT OF UNDERLYING THEORY

The approach to this area of work is varied. Some teams have concentrated their activity in one field of the model shown, whereas some have worked holistically towards offering design advice.

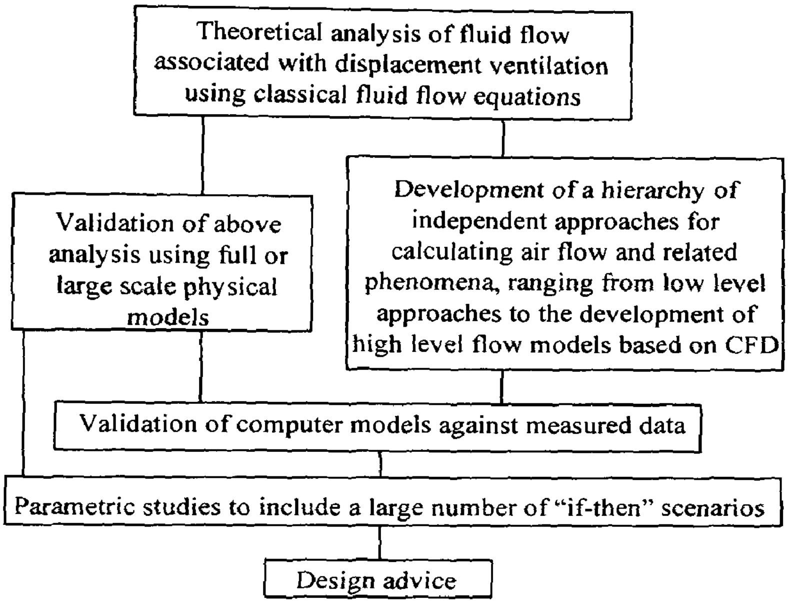

Fig.2. Research Model

Single focus research has contributed some useful findings as described below:

Mundt[7], was not satisfied that earlier work had fully investigated the relationship between temperature gradient in a space and the convective flows from heat sources. This knowledge is essential to the successful design of displacement ventilation as the height of the interface between the "lake" of clean supply air and the contaminated displaced air is dictated by the flow rate of the plumes[1] in test rooms. By detailed measurement incorporating a number of different heat sources, a model was developed to give values for convective flows in the presence of a temperature gradient.

Sandberg[8] has investigated the effect of movement of a heat source within the space, (i.e. a person walking across the office), and concluded that movement lowers the stratification height and causes oscillations of the interface. This was predicted by mathematical modelling, and confirmed by conducting tests on a scale model.

This work identifies a possible problem although a view is put forward by Wyatt[9] that a thin "personalised" boundary layer of fresh air is maintained in the breathing zone despite the lowering of the interface. This view is supported by Mundt[7a].

Tinker and Woolf[10] have investigated the effect of environmental parameter assumption made when modelling to predict environmental conditions in a space.

The problem for the modeller is to keep the model as simple as possible without losing accuracy. This is usually achieved by analysing dimensionless characteristics such as the Archimedes and Rayleigh numbers which can indicate the relative importance of the physical parameters. This will then allow assumptions or simplifications to be made with confidence that there is no significant effect on the accuracy of the result.

Their technique was to compare experimental data from a quarter scale model with results from a dynamic thermal model and CFD simulation. The work is still on-going but they have already provided useful data for other researchers. They also identify that if modellers included their environmental parameter assumptions when publishing results, comparisons could be made with greater confidence.

Examples of the "total concept" approach to research generally include the verification of a CFD package as a design aid.

Alamdari[2] has used a combination of site measurements and computer modelling to confirm the variation of room air temperature with height with displacement ventilation. Confidence is expressed in the CFD modelling to investigate further the problems of floor level obstructions and down flow from cold surfaces.

Holmberg[11] turned to computer modelling as the air velocities in the test room were too low to measure in experimental work to demonstrate that a horizontal displacement effect could be achieved without help from thermal forces. A similar conclusion was made by Alamdari[2].

3 LIMITATIONS OF APPLICATION

A number of claims are made about the amount of cooling that can be handled by a displacement ventilation system. 70 - 100 w/m^2, M Konegi[12] 40 - 50 w/m^2 C Twinn[13] are examples that show that there are conflicting views. This may be the reason that designers are looking for additional cooling via "static" devices.

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Säteri and Kojanei[18][12] both make reference to the possibility of a problem with CO_2. As it is denser than air, there is a possibility of it being trapped in neutral buoyancy with a displacement system. If this were to occur at the breathing zone height this would be very unsatisfactory. It is more likely that neutral buoyancy entrapment will be a problem with small airborne particles.

4 PREVIOUS WORK ON DISPLACEMENT WITH STATIC COOLING

A number of researchers[1][2][12] have suggested that downward convection due to cold surfaces such as windows or cold external walls will seriously disrupt the buoyancy driven displacement flow. This is considered a sufficient disturbance to break down the stratification boundary, mixing air from the contaminated upper zone with the clean lower zone, negating the main benefit of the displacement system.

Kruhne[19] has concluded that displacement ventilation in combination with cooled ceilings, does not always have an advantage over mixing ventilation where air quality is concerned, but that thermal comfort conditions are achieved. Recent physical tests carried out at BSRIA support this finding. Using a model room facility incorporating a displacement ventilation system with chilled panel ceiling, smoke visualisation tests were carried out, releasing test smoke above the false ceiling. It was observed that the room rapidly became contaminated by the smoke. Closer inspection revealed that the smoke was falling through every extract grille, and every unsealed joint in the ceiling. This indicates that air in the ceiling void is being cooled by the reverse side of the chilled panels, and there is insufficient pressure difference between the room and ceiling void to overcome the resulting negative buoyancy.

Although this recirculation effect enhances the heat exchange from the chilled panel, it is destroying the air quality characteristic of the displacement ventilation system. The work at BSRIA concludes that where static cooling devices are used in conjunction with displacement ventilation systems, care should be exercised in the specification and construction of the ceiling, (i.e. sealed joints), to ensure positive air flow from room to ceiling void.[20]

Despite this concern, there is significant research activity into, and in fact commercial application of static cooling with displacement ventilation to counter the risk of thermal discomfort due to high heat gains.[2][9][21][22]

This activity seems to be driven by the over-riding need to reduce design risk of overheating which is easily perceived by the building occupants at the expense of air quality which is less tangible.

This research activity could arguably be overlooking current design philosophy in two major respects in addition to the air quality concerns. The positioning of static cooling at ceiling height introduces a false or lowered ceiling with the following consequences.

* the creation of a barrier to building fabric thermal storage by ceiling slab.

* the depression of high temperature zone towards the occupied zone.

An alternative method of applying static cooling to the displacement ventilation system is proposed by Ma[23], who suggests supplying chilled water to the heating system radiators. This will provide some cooling effect without the disadvantages identified above, and as the radiators are located low in the pool of clean air, their downward convection should not significantly reduce air quality and may in fact assist the displacement flow. This system also has cost benefits over a chilled ceiling, but further work is required as there is little information of the cooling performance of radiators, or the ratio of radiant to convective output.

5 RECENT WORK

One element of the work at BSRIA has been to establish the limitations of displacement ventilation in dealing with heat loads. It has been recognised that the primary limitation is the amount of air that can be provided through conventional displacement diffusers without causing discomfort due to draughts. Preliminary studies carried out at BSRIA using a fabric diffusers indicate that it may be possible to deal with higher heat loads without causing draughts.

With a heat load of $50W/m^2$ and an air change rate of 9.3 per hour, conditions were monitored in the test room, and then compared with earlier results from the same room using standard bin diffusers when the heat load was 40 W/m^2 and the air change rate 3.5 per hour.

Fig 1 shows that despite the slightly higher load the average air temperatures in the room were significantly lower using the fabric diffusers with the higher air change rate, as would be expected. However, Fig 2 shows that the average velocities produced by the fabric diffusers were very similar to those produced by the bin diffusers.

Fig.1

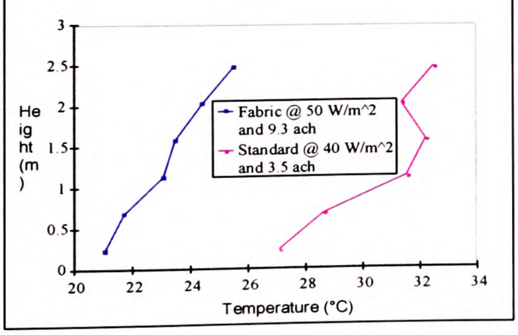
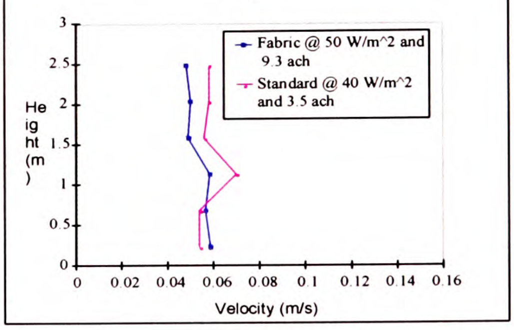


Fig.2



6 CONCLUSIONS

In the field of research into Displacement Ventilation examples have been found of contradictory research findings. This can be explained at least in part, because the objectives, parameters considered, and assumptions made were different. There appears to be some merit in attempting to standardise this, for example, when establishing the ventilation effectiveness of displacement systems a standard measuring point for level of contaminant should be stated.

Particular problems that require further research to reduce the design risk in applying displacement ventilation systems more widely are:

i) environmental performance assessment and comparison of displacement ventilation with chilled ceiling devices and displacement ventilation with low level wall mounted systems (such as radiators).

ii) the problem of identifying suitable comfort criteria for displacement ventilation. The work by Chow[6] suggests that draught at higher temperature could make people more comfortable. If this could be confirmed it would introduce the possibility of a "purge cycle" linked to temperature, to introduce a large volume of cooler air to an overheating space in a short period of time. Chow's work suggests that this may be considered a welcome change rather than an uncomfortable situation as dictated by conventional thermal comfort theory.

iii) consistency of input data for CFD analysis, particularly in representation of air terminal devices, heat sources, moving objects and also in appropriate mathematical modelling of radiation heat transfer.

iv) the problem of dealing with higher cooling loads, without resorting to static cooling with the associated problems identified in 4 above, should be addressed. Geens presents the hypothesis that the number of applications for displacement ventilation without static cooling could be increased if larger air volumes could be supplied without causing draughts at low level. Initial tests with a diffuser that may satisfy this criteria indicate that improved thermal comfort is achieved without creating draughts. Further physical tests and CFD modelling are proposed.

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